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PROCEEDINGS

Symposium for the Management of Pines of the Interior South

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FORWARD

In his welcoming talk Max Young, State Forester of Tennessee, pointed out that nearly 5 million acres of the 13 million acres of forest land in Tennessee needed conversion to pine. This opportunity prevails across the Interior South from western Virginia to Missouri. But what species should be used?

Shortleaf, Virginia, and white pine are native to much of the Interior South. Speaking in the very broadest of generalities we can recommend white pine for moderately drained sites in the Blue Ridge, Valley and Ridge, and Appalachian Physiographic Regions; shortleaf or Virginia pine for dry sites in the Upper Coastal Plain, Upper Piedmont, Blue Ridge, Valley and Ridge, Appalachian and Interior Low Plateaus; and shortleaf for dry sites in the Ouachitas and Ozarks. But generalities are not good enough to guide the decisions necessary in the practice of intensive forestry. Hence, this Symposium was conceived as a forum in which we could bring together all of the available information on the management of shortleaf, Virginia, and white pine. It has also pointed out some of the voids in our bank of knowledge. Indeed the reader may conclude that as many questions have been raised as have been answered. One very logical question is, "Why not plant loblolly?"

Even though loblolly pine has been planted with some degree of success in Kentucky, Illinois, Ohio, and West Virginia foresters should weigh the facts carefully before planting loblolly in areas where it is not native. Snow and ice, but most important of all, cold temperatures limit moving loblolly too far north. Loblolly from northern seed sources can survive and grow well where the average annual rainfall is 43 inches or more; average mean January temperature 37^{o} or higher; and the minimum temperature no lower than -10^{o}F. Whether loblolly can grow under more extreme conditions is questionable. When in doubt go with the native species.

We want to acknowledge the contribution of the Symposium moderators who set the stage for each session and kept the dialogue moving. They were: Max Young, State Forester, Tennessee; Gary Schneider, Head, Department of Forestry, Fisheries and Wildlife, University of Tennessee; Charles Baird, Professor of Forestry, University of the South; Van Michael of Vale Forest Tree Farms; Larry Lassen, Director, Southern Forest Experiment Station; and Robert Hitt, Staff Director, Southeastern Area, State and Private Forestry.

We also want to thank Edward Buckner, University of Tennessee, for handling the local arrangements; John Sharp, Extension Service, University of Tennessee, for coordinating registration; Eyvind Thor, University of Tennessee, for arranging the Christmas Tree Culture session; and Charles Aulds and James Short, Cherokee National Forest, for handling the field trip.

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NATURAL REGENERATION OF SHORTLEAF PINE

by

Edwin R. Lawson 1/

Abstract.--Natural regeneration with the shelterwood and seed tree systems is a viable method for establishing and managing shortleaf pine stands. An adequate seed source, a suitable seedbed, and control of competing vegetation are the primary prerequisites for establishing new stands.

Shortleaf pine (Pinus echinata Mill) is an important commercial species on millions of acres of forest lands and occupies a wide variety of sites from southeastern New York and New Jersey into eastern Texas and eastern Oklahoma. Where shortleaf occurs as the primary softwood species, about one-third to one-half of the existing stands will be regenerated naturally. Also, natural regeneration may be the most common method of regenerating shortleaf pine on much of the vast private forest land throughout its range.

Silvicultural Systems for Natural Regeneration

Forest managers practicing natural regeneration can choose to manage either even-aged or uneven-aged stands. In uneven-aged management, probably only the group selection system is desirable for managing shortleaf pine. Single tree selection is difficult to implement and maintain in mixed pine-hardwood stands, which are common throughout the natural range of shortleaf pine. The group selection system may work well on small forest ownerships or other holdings where it fulfills special management objectives (Gibbs, 1975).

In even-aged management, the shelterwood and seed-tree systems are the alternatives for natural regeneration. In the shelterwood system, the mature stand is removed in two or more cuts. Regeneration of a new stand occurs under a partial forest canopy, which is completely removed when the stand is adequately stocked with seedlings. The shelterwood system is especially beneficial where shelter is needed for reproduction or where the overstory is needed to suppress hardwood growth. Growth rates of residual stems also increase because of thinning and may increase more if additional understory control is provided (Bower and Ferguson, 1968; Yocom, 1971).

With the shelterwood system, reducing the pine stocking to as low as 50 sq. ft. of basal area per acre may be desirable. Phares and Rogers (1962) found that more seed was produced at this basal area than at higher levels and suggested that maximum seed production per acre might occur at even lower levels of stocking. Besides resulting in greater seed production, such stocking levels greatly reduce competition for seedlings.

The seed tree system, probably the most widely used in natural regeneration of shortleaf pine, involves removal of all of the overstory except 6 to 10 well-spaced, vigorous trees. As with the shelterwood system, seed trees should be

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removed when reproduction is adequate.

Some managers prefer to leave 10 to 12 seed trees for added protection against loss of seed trees. Widely scattered seed trees are not as resistant to windthrow as the more dense residual stands of the shelterwood system. In shallow, rocky soils where taproots do not develop, windthrow hazard is increased. Also populations of Ips and other beetles may build up in logging slash and attack seed trees. Prescribed burning may also destroy seed trees if slash is not removed from around the bases of trees before burning. Lightning also kills some trees, and losses to lightning may be critical where few seed trees are left.

Losses of seed after it reaches the forest floor are high but variable. On the average, only about 1 percent of the sound seed dispersed produce seedlings (Yocom and Lawson, 1977). Birds, animals, and insects may eat the seeds. Some seeds fall where they do not get enough moisture to germinate, and seedlings from seeds that do germinate may die before their roots reach mineral soil. High mortality may also result from dry periods after seedling establishment.

Seed Production

Annual production of seed by shortleaf pine trees varies greatly, ranging from near zero to more than a million seeds per acre in moderately stocked stands. In one study (Yocom and Lawson, 1977), an average of 10 seed trees per acre produced 3-year totals of from 308,000 to 916,000 sound seeds per acre.

Many factors contribute to the success or failure of seed crops during the 2 years required for maturity. In early stages of seed development, temperature and evaporation may limit successful fertilization of female strobili (Lamb, et al., 1973). From the beginning of strobili development through cone maturity, losses to insect predation are high. Other organisms and weather conditions cause losses, and many seed abort from unknown factors.

Predicting seed crops very far in advance is difficult. Probably the best predictor is the presence of maturing cones during the growing season before cone maturity. This indicator is not infallible, however, since seed quality can vary greatly. For example, limited data from seed collected in traps in the Ouachita Mountains in the fall of 1975 indicated that 22 percent of the seed were defective. Half of one shortleaf pine bumper seed crop in the Piedmont were found defective (Haney, 1957).

Several silvicultural practices can enhance good seed crops. First, trees left as seed trees should be selected on the basis of vigor, size (particularly crown size), and past cone production. Generally, pine seed trees should be at least 12 inches d.b.h. This minimum diameter provides trees old enough to produce large cone crops and large enough to provide distribution of the seed. Shortleaf pines usually do not produce seed abundantly before they are 20 years old, although there are examples of seed production on trees much younger than 20 years (USDA, 1965). A seed tree cut usually does not leave young trees unsuitable for seed trees. Very old, (100 years or older) slow-growing trees should also be avoided, but if trees are vigorous, there is probably no upper size limitation. Also, trees that have only a few old cones should not be selected for seed trees.

Secondly, because reduction of competition increases both the number of cones and the number of sound seed per cone, most harvest cuts and subsequent understory vegetation control will increase seed production. One study showed that releasing seed trees from surrounding competition doubled the average cone production per tree (Yocom, 1971). Untreated trees produced an average of 498 cones, while released trees produced 1069. Release also increased the average number of seeds per cone from 35 to 38. Percentages of sound seed were 81 and 85 for unreleased and released trees, respectively. Partial girdling also increases cone production (Bower and Smith, 1961). Phares and Rogers (1962) found that shortleaf pine seed production was significantly increased by thinning and hardwood removal.

Site Preparation

Adequate site preparation for natural regeneration of shortleaf pine must provide two basic requirements: (1) a seedbed without heavy litter accumulation so that radicles of germinating seeds can reach mineral soil, and (2) control of competing vegetation.

Seedbed preparation: Often, just the disturbance caused by harvesting the overstory removes enough litter to prepare the seedbed adequately. Litter usually decomposes rapidly when stands are opened during timber removal and hardwood control operations (Smith, 1960). Most litter will be gone after being exposed for one summer, particularly on south and southwest aspects. On some sites, however, litter accumulation is a problem. When litter is redistributed during harvesting and mechanical preparation, mineral soil is also exposed. In the Ouachita Mountains, Yocom and Lawson (1977) found that an average of 35 percent of the surface area was disturbed by logging.

Prescribed burning also removes litter and logging debris effectively. Yocom and Lawson (1977) found that burning and logging enhanced seedbed conditions and increased tree percents (ratio of established seedlings to sound seed produced x 100) as follows:

Burning treatment	Logging Disturbance	
	Undisturbed	Disturbed
	Tree Percent	
Unburned	0.42	0.98
Burned	0.98	1.29
	Percent Stocking	
Unburned	53.5	74.5
Burned	82.7	87.8

Both burning and logging disturbance resulted in similar tree percents and percent of milacres stocked. Thus, either burning or disturbance may satisfy seedbed requirements. Burning, however, generally provides seedbed conditions that are more uniform than those provided by logging disturbance alone.

Timing of seedfall in relation to seedbed preparation is also important. If spring or summer cone counts indicate low seed production, seedbed preparation should be delayed until the next year. Otherwise, litter accumulation

and growth of herbaceous vegetation before the next seedfall may negate the benefits of seedbed preparation.

Competition Control. On most sites, competition for water and light becomes critical to newly established seedings. Competition control should be implemented before seedfall or before growth starts the next spring. Burning, if it is part of site preparation, must be done before seedfall.

On typical pine sites, many hardwoods are present and must be controlled to allow adequate natural regeneration. Single stem injection or spray application of herbicides effectively reduces hardwood competition. If many very small hardwoods are present, spray application and perhaps single stem injection may be necessary. Mechanical methods, such as hand cutting and shearing, also reduce hardwood competition but may cause problems with sprouting. Maple (1965), however, found that a brushcutter provided higher tree percent and stocking levels than chemical treatment or burning.

On south facing slopes, achieving total hardwood control may not be necessary. In the Ouachita Mountains, Yocom and Lawson (1977) found that single and repeated hardwood control treatments on north aspects resulted in tree percents of 0.91 and 1.03, respectively. On south facing slopes, however, these two values were 0.97 and 0.76. Southern slopes are drier than northern ones, and some residual hardwood stems may benefit pine for the first few years by shading and protecting it from drying winds.

If adequate regeneration is not achieved within about 3 years after site preparation, additional site preparation may be needed. Our experience in the Ouachitas indicates that we can reach this objective where hardwoods are controlled with chemicals followed by burning on some sites. On better sites, hardwood regrowth will likely be so rapid that seedlings will have little opportunity to become established, even if they are planted soon after site preparation. Because most herbicide sprays may harm pine seedlings, sprays should not be used during the first year or two after establishment (Lawson, 1960).

Stocking Control

Getting the right number of seed and seedlings distributed over the area being regenerated is often difficult. We have some control over stocking by the number of seed trees left for regeneration. One study (Yocom, 1968) in the Ouachita Mountains showed that most shortleaf seed fell within 2.5 chains from the seed source. One-half the seed fell within one chain of a forest wall (stand of mature trees adjacent to a clearcut or seed tree area) and 85% fell within 2.5 chains of it. In 1964, 16,600 to 31,500 seeds per acre fell in traps 2.5 chains from the wall. At 1.5 chains from the wall, number of seed approached 42,700 or about a pound per acre. Neither prevailing winds nor shifting winds made a significant difference in seed catch, although they have in other studies (Little, 1940; Siggins, 1933). About 2 1/2 times the tree height is about the maximum distance over which a tree will distribute seed. Thus, about 6 to 10 well-spaced seed trees per acre should distribute enough seed to cover the area, with a little extra for insurance.

If a seed crop fails and hardwoods have just been cut, burning the area and either planting or direct seeding may be necessary. If regeneration is not accomplished during the first year, competition may prevent regeneration

without additional site preparation. If hardwood control has been accomplished with chemicals, development of competing vegetation is slower and more time is available for seedling establishment.

One of the big problems with natural regeneration is getting too many seedlings. This usually happens when a good seed crop, adequate rainfall amount and distribution, and a suitable seedbed combine. But overstocking may also occur because mature seed trees are left too long. To avoid leaving seed trees too long, count established seedlings after each growing season.

Ideally, the seedling count should be made in late summer or early fall in time to remove the seed trees if adequate numbers of seedlings are present. Where dense herbaceous and other vegetation occurs, however, making an accurate inventory may be nearly impossible in late summer, so the inventory should be postponed until just before vegetative growth begins in late winter or early spring. The disadvantage of a spring count is that the number of seedlings that will be established at the end of the next growing season is unknown. If a good seed crop occurred the previous fall and the regeneration area is approaching full stocking, you may want to go ahead and remove the seed trees.

If overstocking occurs, reduce the number of seedlings to a suitable level as soon as feasible. If post markets are available, however, delaying thinning until most trees are merchantable may be desirable. Best thinning methods for upland sites have not been determined. Hand thinning or strip cutting with brush cutters and drum choppers have been used. Up to about post size, shortleaf pines severed above ground will sprout and are likely to remain as competitors for water and nutrients. Perhaps use of herbicides for thinning would be possible, but to my knowledge no guidelines have been developed for this method.

Natural regeneration may create overstocking problems next to forest walls on areas that have been (or will be) planted or direct seeded. Invading natural seedlings can cause a serious problem in plantations where genetically improved seedlings have been planted. Distinguishing natural from planted seedlings may be difficult at early ages. Natural seedlings may be present before harvesting and site preparation and will readily sprout back with vigorous growth if damaged by fire or equipment. I have observed newly germinated seedlings in the middle of large areas that were harvested, sheared, windrowed, and burned the previous summer. The presence of these seedlings suggests that all shortleaf pine seeds may not germinate the first year after seedfall, but this phenomenon has not been documented in the literature.

On many sites throughout the shortleaf range, natural regeneration is a viable management alternative and may be the only practical alternative on steep, rocky sites. On much private forest land, natural regeneration may be desirable because it is less expensive than clearcutting followed by site preparation and planting.

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PLANTING AND SEEDING SHORTLEAF PINE

T. E. Russell[1/]

Abstract.--Shortleaf pine can be readily established by direct seeding or planting on a wide variety of sites. On cutover sites, providing adequate control of unwanted hardwoods is essential for satisfactory survival and growth.

Additional key words: *Pinus echinata* Mill., artificial regeneration of pines

Most shortleaf stands are of natural origin, although millions of shortleaf pines have been planted and large acreages seeded. Natural regeneration, either planned or fortuitous, will most likely continue to dominate shortleaf management in the future. Nevertheless, planting and seeding have been attractive to landowners in the past and a need for artificial regeneration will almost certainly continue.

One problem that occurs in natural shortleaf stands is clumpy distribution; bare spots beside dense thickets are not uncommon. Planting or seeding can minimize this occurrence and reduce the expense of precommercial thinning. These methods offer the opportunity to get superior seedlings into the forest, and with planting strict control of both spacing and distribution are also possible.

PLANTING

Shortleaf planting procedures are basically the same as for any southern pine species and sufficient experience has been gained with seedling production, stock handling, and planting techniques to expect a consistently high level of success. Detailed instruction is available in *Planting the Southern Pines* (Wakeley 1954), which remains the most complete guide available. Limstrom (1963) offers additional information applicable to planting shortleaf in the central and northern portions of its range. Key requirements for planting shortleaf are selection of a suitable site, use of the best available planting technology, and adequate control of competing vegetation.

Site Selection

Shortleaf pine grows throughout the East on a wide variety of soils and we know enough about shortleaf's site requirements to have little difficulty in selecting a planting site capable of satisfactory growth yields (Fowells 1965).

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Planting Technology

Control of seedling quality, stock handling, and planting operations is essential. Poor initial survival usually results from lack of care in shipping, storing, and handling stock, especially when compounded with poor planting.

In general, nurseries produce high-quality shortleaf seedlings. In the future they will perhaps supply seedlings that are inoculated with strains of mycorrhyzae for planting on specific soils.

Seed source is also important. When research or experience indicates superiority of a specific non-local seed source, that source should be used. If such information is not available, seeds should be obtained from as near the planting site as possible.

Seedlings should not be allowed to dry, heat, or freeze during shipment, storage, or planting. They can be kept safely in bales for 2 or 3 weeks in a cool, shaded place and can be heeled-in for longer periods but should be planted before the buds break. Refrigeration at about 36° F is best for long-term storage (Limstrom 1963).

Optimum planting dates vary with local climate. In regions with severe winters, seedlings planted in fall or winter may be injured by frost heaving, particularly on heavy soils and where intensive site preparation has removed all cover. Planting bare-rooted seedlings in late spring is generally not advisable because of the increased risk of hot, dry weather after planting. Container-grown stock is becoming increasingly available and can be used to extend the planting season into late spring or early summer.

Shortleaf pine seedlings can be planted by machine or by various hand methods. Spacing depends upon expected survival, length of rotation, product size objective, and whether or not plantations can be thinned profitably. There is no point in planting at such tight spacing that costly precommercial thinning will be needed to maintain stand vigor and desired rate of diameter growth.

Competition Control

Shortleaf pine is intolerant of competition and control of vegetation is essential for satisfactory plantation performance (Fowells 1965). In the future there will probably be very little abandoned agricultural land available for planting. Therefore, major competition will be either understory hardwoods and brush left after harvesting of existing pine stands or unmerchantable hardwoods growing on sites where type conversion is the objective.

With few exceptions, pine will be established on sites where the climax forest is an oak or oak-hickory type. Natural succession must therefore be arrested, and this is not always an easy task. Depending upon site quality, shortleaf pines may grow from about 15 to 25 feet in height during their first 10 years; hardwood sprouts often grow at even faster rates on most cutover sites.

Shortleaf pine's reaction to competition may differ somewhat between regions. In the Ozarks planted seedlings weakened by severe hardwood competition have been slow to respond to release (Liming 1946). On the Cumberland Plateau seedlings underplanted in a low-grade hardwood stand, and suppressed for 2 years, promptly resumed good growth after the overstory was deadened (Russell 1963, 1969). However, about 1 year's height growth was lost for each year of deferred release.

Mechanical treatments, herbicides, and fire, alone or in various combinations, can be used to prepare sites (Fitzgerald et al. 1973, Peevy and Brady 1972). Choice of method depends upon site characteristics and upon composition and density of existing vegetation. The essential point is that competition control methods are the same for planting shortleaf pine as for any other species.

Severity of competition, and degree of control needed, depends primarily upon the quality of the site and its past use. Conditions vary greatly, and no single technique or intensity of treatment will apply to all situations. The following examples illustrate some common site preparation problems that may be encountered.

Most planting on the Cumberland Plateau in Tennessee is designed to convert from hardwood to pine. Many candidate areas have a closed hardwood canopy of pole size or larger trees with only a light overstory of hardwood reproduction and brush. Such stands present an excellent opportunity for underplanting and release; controlling overstory hardwoods by tree injection or frilling is usually all that is needed.

If stands have a moderately dense to dense understory, the understory hardwoods must also be controlled. Understory control is more complex than overstory elimination and there are several solutions.

It is futile to attempt control of small hardwoods by simply cutting them at planting time; fast-growing sprouts will soon suppress shortleaf seedlings. Adequate control can be achieved either by injection, by cutting and treating stumps with a herbicide, or by basal spraying. Where small hardwoods are too numerous for single-stem treatments, foliar sprays can be applied with ground or air equipment. When herbicides are applied from the air it is advisable to remove the overstory first either by logging if trees are merchantable or by deadening early enough to fully expose understory vegetation.

Areas can also be cleared mechanically, eliminating both small and large hardwoods in one operation. Shearing and disking usually provide satisfactory and long-lasting control of woody vegetation. But, such intensive treatments can be performed only on sites with gentle topography and nonerodible soils. Where sites are prepared only by shearing, or tree-crushing, chemical spray treatment is often needed to control subsequent sprouting.

A useful but less desirable method is to treat only those overstory stems more than 2 inches or so in diameter before planting and follow with treatment after 3 to 5 years to control smaller hardwoods. The final treatment is usually done with foliar sprays applied at about half the rate needed for site preparation. Single stem treatments can be used where there are relatively few stems per acre to treat.

The most severe competition for planted pines occurs on cutover areas on good sites that have been invaded by hardwoods and brush. This vegetation is usually incipient in the understory of mature stands and responds vigorously to overstory removal. The problem worsens when there is a delay between harvest and planting. Cutover areas on the Cumberland Plateau, for example, may accumulate up to 50,000 undesirable woody stems per acre within 5 years. The only practical way to eliminate such dense thickets is by mechanical clearing or chemical sprays; satisfactory control with herbicides may require repeated applications.

Fire can supplement mechanical or chemical treatments, but fire alone seldom provides sufficient site preparation. On the Cumberland Plateau, single burns usually intensify competition by greatly increasing the number of hardwood sprouts (Williamson 1964). Tree-crushing followed by burning has been effectively used to prepare sites in the Ozarks.

Direct Seeding

Compared to planting, direct seeding has the advantages of low labor requirements and substantial cost savings. Direct seeding is also the most efficient way to restock large areas quickly or to reforest areas that are hard to plant because of rugged topography, rocky soils, or heavy logging slash. Major disadvantages are the complexity of recommended seeding procedures and the risk of understocking or overstocking, especially when broadcast seeding.

As with any southern pine species, key requirements for direct seeding shortleaf are 1) selection of suitable sites, 2) provision of suitable seedbeds, 3) protection of seeds from birds and rodents, 4) sowing of enough sound seeds from a suitable seed source at the right time, and 5) adequate control of competing vegetation.

Site selection, competition control, and considerations of seed source are similar for both direct seeding and planting; seedbeds, seed protection, and sowing rates, and sowing methods are unique to direct seeding.

Seedbeds

For broadcast sowing, optimum germination is obtained only if seeds are in contact with moist mineral soil. Although logging may provide a good amount of scarification, additional seedbed preparation is usually needed to establish enough well-distributed seedlings.

On the Cumberland Plateau in Tennessee, light disking worked well in open woods and was better than burning (Russell and Mignery 1968). Bulldozing and heavy disking have also satisfactorily prepared difficult sites on the Plateau (Sander 1963).

Mechanical site treatments are ordinarily expensive and are best used primarily to reduce competition. Any mechanical treatment thorough enough to control dense stands of small hardwoods will provide an excellent seedbed as a secondary benefit. To minimize seed losses from washing and silting, allow sites to settle for at least 2 months before sowing.

Where hardwoods are controlled with chemicals, fire can be used to prepare seedbeds. Burning is the only practical way to reduce deep litter where steep slopes or rocky soils do not allow mechanical preparation. On sites with a deep and matted hardwood litter, fire may produce only fair seedbeds unless the lower layers of litter are very dry.

With spot and furrow seeding, seeds are placed directly on the mineral soil and, theoretically, no area-wide seedbed treatment should be needed. In practice, however, drifting hardwood leaves often cover seed spots and furrows deeply enough to prevent seedling emergence. Moreover, clipping of newly-germinated seedlings by mice may be more severe on litter-covered sites. Thus, areas with a deep and continuous hardwood litter should be burned before furrow or spot seeding (Croker 1964, Russell and Mignery 1968). This burn can be of low intensity, since the goal is to remove only the loose surface leaves. If burning can not be done, seed spots should be raked clean over an area of 1 foot or more in diameter and seeding deferred to as late in spring as is consistent with obtaining good germination and seedling establishment.

Seed Protection

To minimize losses to birds and rodents, coat seeds with the best repellent available (currently Arasan 42-S plus Endrin)[2/]. Arasan 42-S is now registered for use as a bird repellent. The future of Endrin is unclear but appears hopeful as a rodent repellent (Bill Mann, Personal Communication).

Untreated seed sown at two or three times the normal rate usually yield about as many seedlings per acre as the normal rate of treated seed. This relationship may not be true everywhere and is an expensive and risky way to combat seed depredations. Heavy animal pressures may cause complete failure, despite much seed, and if animals are scarce the new stand will be overstocked.

Sowing Rates and Dates

For broadcast seeding in the Missouri Ozarks, 24,000 viable seeds per acre are recommended (Seidel and Rogers 1965). This rate is about one half pound per acre for the average seed lot. On favorable sites in Tennessee, 10,000 sound seeds per acre are adequate, if seedbeds are well prepared. On less favorable sites or where seedbeds are less than optimum (as on many burns) the seeding rate should be increased to 20,000 seeds per acre (Russell and Mignery 1968).

2/ Mention of trade names does not imply endorsement by the U.S. Department of Agriculture.

Furrow seeding requires one seed per 9 to 12 inches of furrow; seed spots should have at least five seeds. For any method of seeding, it is better to sow at a relatively high rate during initial trials. Rates can then be reduced as experience is gained and as requirements for specific local sites are determined.

Choice of seeding date varies somewhat from region-to-region. In the Ozarks, Seidel and Rogers (1965) recommend seeding between December 1 and April 15. In Tennessee, satisfactory germination and stocking have been obtained with seeds sown between December and May. Stratified seeds should be sown in spring; in winter, dry seeds should be sown. The change from dry to stratified seed should be made 2 to 4 weeks before the average date of the last killing frost.

The preceeding discussion highlights major factors in seeding shortleaf pine. Also important are: details of storing, treating, and testing seed; seed tool calibration and use; and planning, performing, and evaluating direct seeding operations. Further information is available in Derr and Mann (1971).

Conclusion

Shortleaf pine can be established readily by either planting or direct seeding. Planting is more expensive, but requires less skill and involves fewer uncertainties. For most situations in the Interior South, planting will probably be preferred over seeding because of the control it provides over seedlings per acre and distribution.

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GROWTH AND YIELD OF SHORTLEAF PINE IN MISSOURI:

21-YEAR RESULTS FROM A THINNING STUDY

by

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ABSTRACT

Net cubic foot and board foot volume yields of 30-year-old shortleaf pine stands thinned twice at 10-year intervals to the same basal area were significantly higher when thinned to densities of 90 square feet basal area per acre or above than when thinned to lower densities. The density at which periodic annual net volume growth was greatest increased with time. Basal area growth was lowest for plots thinned to 50 square feet basal area/acre and varied little for plots at higher densities. The presence of hardwoods reduced growth and yield by 8 to 12 percent.

INTRODUCTION

A basic objective of timber management is to produce the most high quality timber possible in the shortest period of time. Manipulating stand density by thinning helps accomplish this goal because trees that would be lost through mortality are harvested and because the remaining trees grow faster in diameter and trees are able to produce usable products quicker.

We began this study in a 30-year-old natural shortleaf pine stand to see how this species responds to thinning. Specifically, we wanted to know how dense the residual stand should be to produce the most wood and what yields can be expected from the thinnings.

THE STUDY

The stand chosen for the study originated after the harvest of a mature oak-pine stand. The area burned periodically until 1933, and has not burned since. When the stand was 15 years old, most of the hardwoods were cut or girdled and the pine was thinned from about 1,100 to 600 trees per acre. Thinning was mostly from below and left the better trees.

At age 30 the stand averaged about 575 shortleaf pine trees and 135 square feet of basal area per acre. The diameter of the tree of average basal area was 6.4 inches. Site index for shortleaf pine averages about 65. A hardwood understory with about 900 stems per acre was present--the most abundant species were dogwood; sassafras; black, white, post, and blackjack oaks; hickories; and black gum.

Four density levels of shortleaf pine were created by thinning--50, 70, 90, and 110 square feet of basal area per acre (Table 1). In addition, an unthinned treatment was left as a check. Two levels of hardwood understory were also tested. On some of the 70 level plots the hardwood understory was left and all hardwoods were left on some of the unthinned plots. On all other plots hardwoods were controlled with herbicides.

Table 1.--Treatment combinations in shortleaf pine study.

Density level [1]	Hardwoods present
50	None
70	None
90	None
110	None
Unthinned	None
70	Understory
Unthinned	All

[1] Basal area per acre of residual stand.

The thinning can best be described as free thinning, in which trees from all crown classes are free to be removed. During thinning the objective was to leave the best possible trees as uniformly spaced over the plot as possible. If it was not possible to leave the best tree and maintain uniform spacing, a second best tree was left.

Plots were first thinned when the stand was 30 years old. Plots were thinned to the designated basal area levels at age 40 and again at age 51.

RESULTS

GROWTH

Annual net basal area growth from age 31 to 40 was highest at the 70 density level and lowest at the 50 level (Table 2)[1/]. It was only slightly higher at the 70 level than at the 90 level but was markedly higher than at the 110 basal area level. Net basal area growth was lowest at the 50 level because the stands were understocked and did not fully occupy the site.

1/ Data in table 2 and subsequent tables are depicted graphically in Figures 1-5 following the text.

Table 2.--Annual periodic growth per acre of shortleaf pine stands thinned to various density levels.

Age period (Years)	Density level 50	70	90	110	Unthinned
	Basal area--square feet				
31-40					
Gross	3.3	3.9	3.7	3.4	3.2
Net	2.9	3.9	3.6	3.1	3.0
41-51					
Gross	2.2	2.7	3.0	3.2	3.0
Net	2.1	2.7	2.9	3.1	1.7
31-51					
Gross	2.7	3.3	3.3	3.3	3.1
Net	2.5	3.3	3.2	3.1	2.3
	Cubic feet				
31-40					
Gross	72	83	79	78	70
Net	67	83	77	73	68
41-50					
Gross	89	125	152	172	189
Net	86	125	152	170	165
31-51					
Gross	81	104	115	125	129
Net	77	104	115	121	116
	Board feet				
31-40					
Gross	423	477	456	516	420
Net	400	477	450	501	416
41-51					
Gross	443	708	869	971	1,027
Net	425	708	857	968	996
31-51					
Gross	433	592	662	743	723
Net	412	592	653	734	706

Basal area per acre of the residual stand.

Trees 4.6 inches d.b.h. and larger to a 3 inch d.i.b. top.

Trees 6.6 inches d.b.h. and larger to a 5 inch d.i.b. top. International 1/4-inch rule.

From age 41 to 51 the highest net annual basal area growth shifted to the 110 level. Net growth at the 90 level was slightly less and at the other levels greater differences occurred. Mortality was not great at any density level except in the unthinned plots where 2.3 square feet per acre were lost each year because trees were severely crowded. Residual basal area in these plots at age 40 was 170 square feet per acre. At the 70 level gross basal area growth was 1.2 square feet per acre per year less than from age 31 to 40. This was greater than the decrease at any other density level and indicates that the 70 level plots as well as the 50 level plots are understocked.

The large decrease in annual basal area growth from age 41 to 51 at the 50 and 70 levels illustrates what happens when stands are repeatedly thinned to the same residual basal area level. In the development of normal even-aged stands, basal area increases until an age is reached when mortality and growth are about equal. If basal area is not allowed to increase when young stands are repeatedly thinned, an understocked stand is eventually created.

Annual net cubic volume growth from age 31 to 40 averaged 83 cubic feet per acre at the 70 level, which was slightly more than at any other density (Table 2). The lowest annual net cubic volume growth was 67 cubic feet per acre and occurred on the 50 level plots and on the unthinned plots. However, the differences among all density levels were not significant. From age 41 to 51 annual cubic volume growth at all density levels was much greater than from age 31 to 40 except at the 50 and 70 levels. Net growth was highest at the 110 level, and gross growth was highest on the unthinned plots.

From age 31 to 40, annual net board foot volume growth at the 110 density level was 500 board feet per acre, which was higher than at any other density. Growth was least at the 50 level and averaged 400 board feet per acre per year. None of the differences in board foot growth among density levels were significant. From age 41 to 51, board foot volume growth was about double the growth from age 31 to 40 at all density levels except the 50 and 70 levels. From age 41 to 51 the unthinned plots grew about 1,000 board feet per acre per year, and the 50 and 70 plots only grew 425 and 700 board feet per acre per year, respectively. Growth at the 110 level was only slightly less than on the unthinned plots.

The trends in volume growth, like basal area growth, indicate that the 50 and 70 density levels are understocked. The plots thinned to the 50 level were understocked after one thinning and the plots thinned to the 70 level were understocked after two thinnings.

YIELD

The yields at age 30 are the result of natural stand development except for the thinning that was made at age 15 (Table 3). No records were kept, so the volume removed in that thinning is not known. At age 40 there is no apparent trend of yield in relation to density level. Yield in both cubic and board feet was slightly higher at the 90 level than at any other level, but the 90 plots had the highest volume at age 30. Although yield at age 40 was lower at the 110 level than at the other densities, these plots had the lowest volume at age 30 and by age 40 were just beginning to catch up. At age 50 the unthinned plots had the highest yield and the 50 and 70 plots had the lowest because of their understocked condition. Yields at the 90 and 110 levels were about equal.

Table 3.--Periodic yield per acre of shortleaf pine thinned to various density levels.

Age (Years)	Density level 50	70	90	110	Unthinned
			Cubic feet		
30					
Gross	2,238	2,278	2,351	2,129	2,354
Net	2,238	2,278	2,351	2,129	2,354
40					
Gross	2,971	3,105	3,138	2,911	3,059
Net	2,907	3,105	3,120	2,861	3,038
51					
Gross	3,945	4,480	4,804	4,802	5,143
Net	3,853	4,480	4,786	4,738	4,909
			Board feet		
30					
Gross	5,939	6,068	6,754	4,930	6,517
Net	5,939	6,068	6,754	4,930	6,517
40					
Gross	10,170	10,834	11,319	10,091	10,713
Net	9,933	10,834	11,247	9,941	10,677
51					
Gross	15,040	18,627	20,883	20,769	22,012
Net	14,675	18,627	20,683	20,587	21,633

Basal area per acre of the residual stand.

Trees 4.6 inches d.b.h. and larger to a 3 inch d.i.b. top.

Trees 6.6 inches d.b.h. and larger to a 5 inch d.i.b. top. International 1/4-inch rule.

During this 21-year period of stand development, ingrowth was an important factor contributing to the growth and yield. At age 30 plots at all density levels had many trees smaller than the 5 and 7 inch threshold diameters used to determine cubic and board foot volume. Therefore, the potential addition to volume by ingrowth was high. By age 40, all trees except those in the unthinned plots were 5 inches d.b.h. or larger or had been removed in the second thinning. Few trees smaller than 7 inches d.b.h. were left in any but the unthinned plots. Thus, potential for substantial gains in volume from ingrowth between ages 41 and 51 existed only in the unthinned plots. Ingrowth volume will be much less in the future because few trees remain that are still below the threshold diameters and some of these, especially in the unthinned plots, will die.

The harvested yield is important because all the trees removed in the thinnings were sold for commercial products. At age 30 the 50 and 70 levels yielded the greatest volume (Table 4). The products were mostly posts, although a few poles and saw logs were also harvested. Ten years later the 70 and 90 levels yielded the greatest volume and products were about evenly divided between posts and poles but also included some saw logs. The most recent thinning, at age 51, yielded mostly poles and saw logs and a few posts. Plots at the 110 level yielded the highest volume. Nothing has been harvested from the unthinned plots.

Table 4.--Volume harvested per acre from shortleaf pine stands thinned to various density levels.

Age	Density level 50	70	90	110	Unthinned
			Cubic feet		
30	1,223	961	724	221	0
40	560	714	634	389	0
51	410	753	791	959	0
Total	2,193	2,428	2,149	1,569	0
			Board feet		
30	2,540	1,680	1,400	230	0
40	2,370	2,870	2,370	1,390	0
51	2,030	3,730	3,900	4,600	0
Total	6,940	8,280	7,670	6,220	0

Basal area per acre of the residual stand.

Trees 4.6 inches d.b.h. and larger to a 3 inch d.i.b. top.

Trees 6.6 inches d.b.h. and larger to a 5 inch d.i.b. top. International 1/4-inch rule.

Table 5.--Periodic annual growth per acre of shortleaf pine with and without hardwoods

Age period (Years)	Thinned to basal area of 70 ft /acre: Hardwoods absent	Thinned to basal area of 70 ft /acre: Understory hardwoods present	Unthinned: Hardwoods absent	Unthinned: All hardwoods present
	Basal area--ft			
31-40				
Gross	3.9	3.4	3.2	3.0
Net	3.9	3.3	3.0	2.5
41-51				
Gross	2.7	2.9	3.0	2.9
Net	2.7	2.7	1.7	1.7
31-51				
Gross	3.3	3.2	3.1	3.0
Net	3.3	3.0	2.3	2.1
	Cubic feet			
31-40				
Gross	83	62	70	57
Net	83	60	68	55
41-51				
Gross	125	106	189	149
Net	125	106	165	132
31-51				
Gross	104	85	129	105
Net	104	84	116	95
	Board feet			
31-40				
Gross	477	373	420	347
Net	477	369	416	344
41-51				
Gross	708	583	1,027	813
Net	708	580	996	793
31-51				
Gross	592	483	723	591
Net	592	479	706	580

Trees 4.6 inches d.b.h. and larger to a 3 inch d.i.b. top.

Trees 6.6 inches d.b.h. and larger to a 5 inch d.i.b. top. International 1/4-inch rule.

Table 6.--Periodic yield per acre of shortleaf pine with and without hardwoods

Age	Thinned to basal area of 70 ft /acre: Hardwoods absent	Thinned to basal area of 70 ft /acre: Hardwood understory present	Unthinned: Hardwoods absent	Unthinned: All hardwoods present
	----------Cubic feet ----------			
30				
Gross	2,278	2,446	2,354	2,520
Net	2,278	2,446	2,354	2,520
40				
Gross	3,105	3,066	3,059	3,091
Net	3,105	3,050	3,038	3,077
51				
Gross	4,480	4,237	5,143	4,728
Net	4,480	4,213	4,909	4,523
	----------Board feet ----------			
30				
Gross	6,068	7.137	6,517	6,939
Net	6,068	7,137	6,517	6,939
40				
Gross	10,834	10,870	10,713	10,413
Net	10,834	10,827	10,677	10,383
51				
Gross	18,627	17,285	22,012	19,361
Net	18,627	17,214	21,633	19,113

Trees 4.6 inches d.b.h. and larger to a 3 inch d.i.b. top.

Trees 6.6 inches d.b.h. and larger to a 5 inch d.i.b. top. International 1/4-inch rule.

When making thinnings, always leave the best trees as uniformly spaced as possible. The best trees are generally dominants or codominants with good form and vigor and well-developed crowns. Basal area of the residual stand must be allowed to increase as stands get older, to maintain a stand that will fully occupy the site, but the older the stand the less the increase has to be. A maximum residual basal area may be attained after age 50, but we have little evidence now of what it might be or at what age it might occur.

EFFECT OF HARDWOODS

The periodic annual net basal area growth of shortleaf pine from age 31 to 40 was better on plots where hardwoods were controlled than on plots where they were not controlled (Table 5). Although the differences in net growth were not large (0.6 and 0.5 square foot per acre per year for the 70 and unthinned levels, respectively), they were significant. From age 41 to 51 net basal area growth was the same within each density level regardless of whether or not the hardwoods were controlled. It appears that competition in the plots without hardwoods is just as severe as it is in the plots with hardwoods. At the 70 level an understory of pine has developed on plots where hardwoods were controlled, and this pine understory appears to be having the same effect on overstory basal area growth as the hardwood understory on other plots. The unthinned plots are overstocked and the competition in plots without hardwoods is just as severe as in the plots with hardwoods.

Hardwoods had a negative effect on annual merchantable volume growth (Table 5). The differences between growth on plots with hardwoods and without hardwoods were not significant at either density level from age 31 to 40, but they were significant from age 41 to 51.

The initial volume yields at age 30 were greater for plots with hardwoods but by age 40 yields were about equal or slightly higher on plots where hardwoods were controlled (Table 6). The faster growth on plots with no hardwoods enabled them to match the yield of plots with hardwoods by age 40 and by age 51 the trend toward greater yield on the plots with no hardwoods was readily apparent. No economic analysis has been made to determine if the higher growth attained by controlling hardwoods is enough to recover treatment cost.

MANAGEMENT IMPLICATIONS

Thinning shortleaf pine stands is a beneficial silvicultural practice that results in increased product yields and shorter rotations. Thinnings should be begun at about age 10 to 15 and continued regularly at intervals of about 10 years. Whether the first thinning will pay for itself will depend on the initial stocking of the reproduction, the availability of markets for small roundwood products, and the minimum volume per acre required for operability but the second and subsequent thinnings should definitely pay for themselves.

The results of our research apply specifically to similar natural shortleaf pine stands in Missouri and should be checked before being applied elsewhere. However, several general preliminary recommendations can be made. The first thinning should be made at age 10 to 15 and although the optimum residual density is unknown, about 600 trees per acre seems reasonable. The second thinning should be made before age 30 and should leave a residual stand of 70 to 80 square feet of basal area per acre. The third thinning should reduce basal area to 90 to 100 square feet per acre, and the fourth to about 100 to 110. Beyond the fourth thinning, or about age 40 to 50, the appropriate residual basal area is uncertain. To be effective, a thinning must benefit the entire stand and leave a stand that fully occupies the site. If only a few trees per acre can be removed, the entire stand will not benefit and so should not be thinned.

Figure 1.--Annual periodic growth per acre of shortleaf pine thinned to various density levels

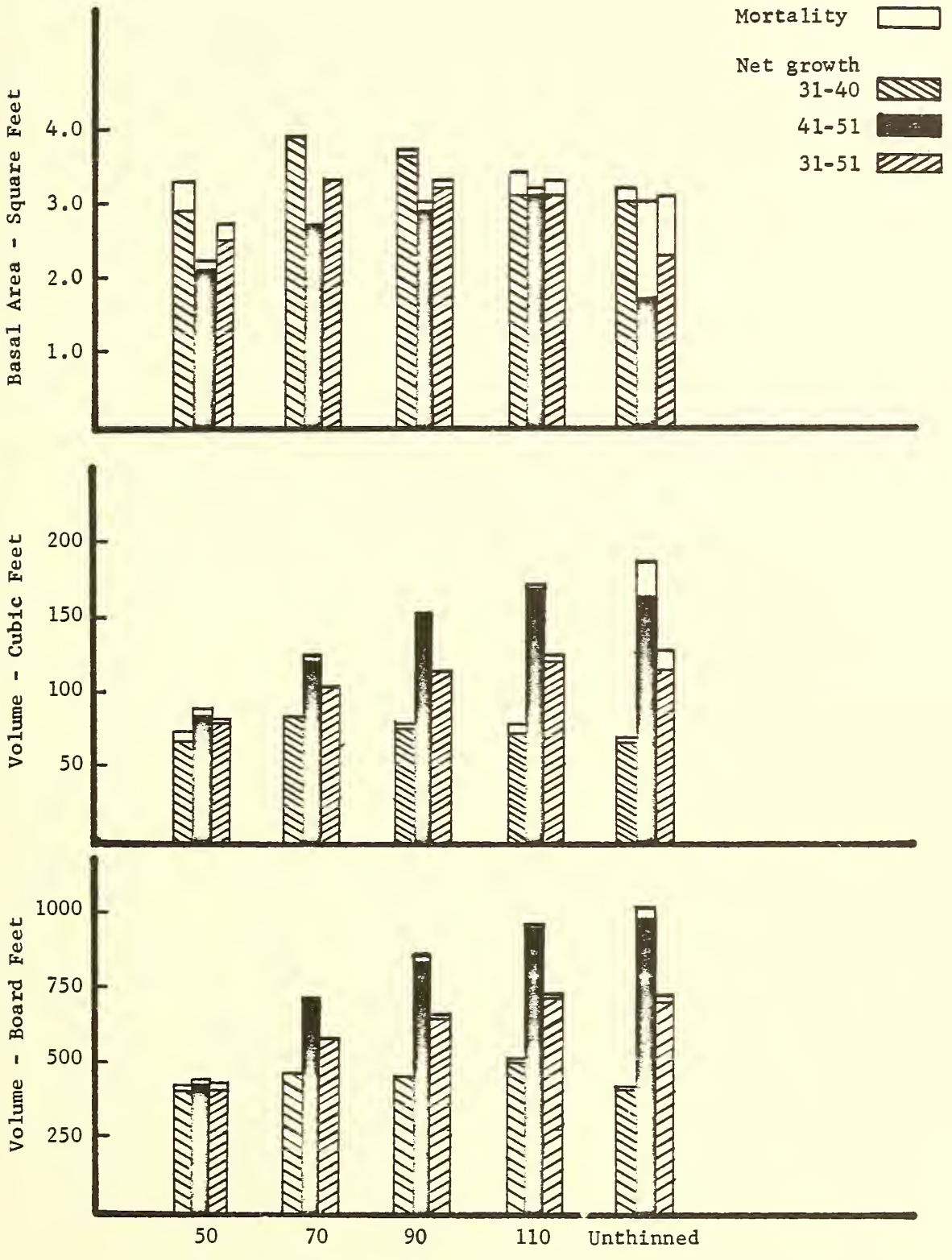


Figure 2.--Periodic yield per acre of shortleaf pine thinned to various density levels

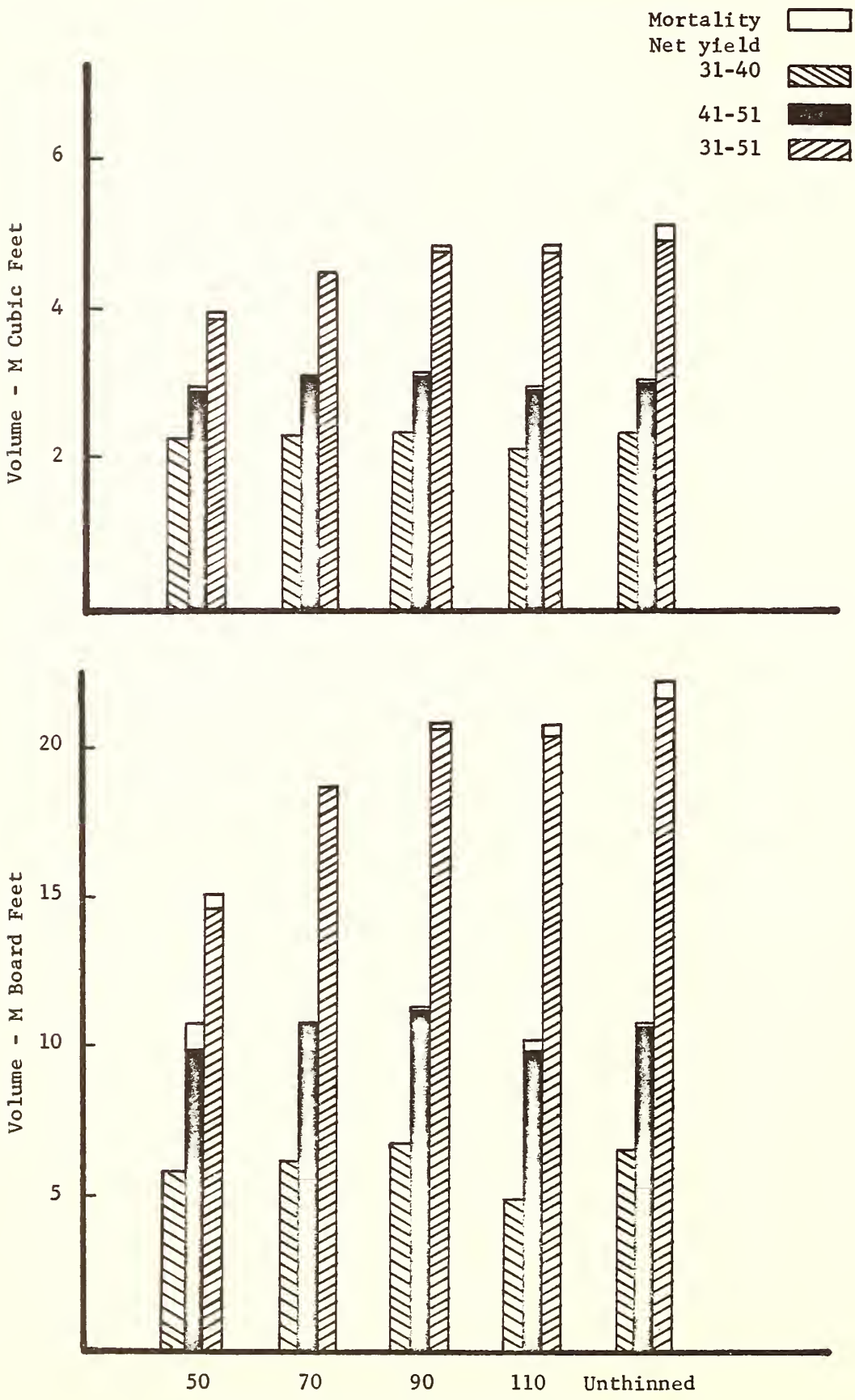


Figure 3.--Volume per acre harvested from shortleaf pine stands thinned to various density levels

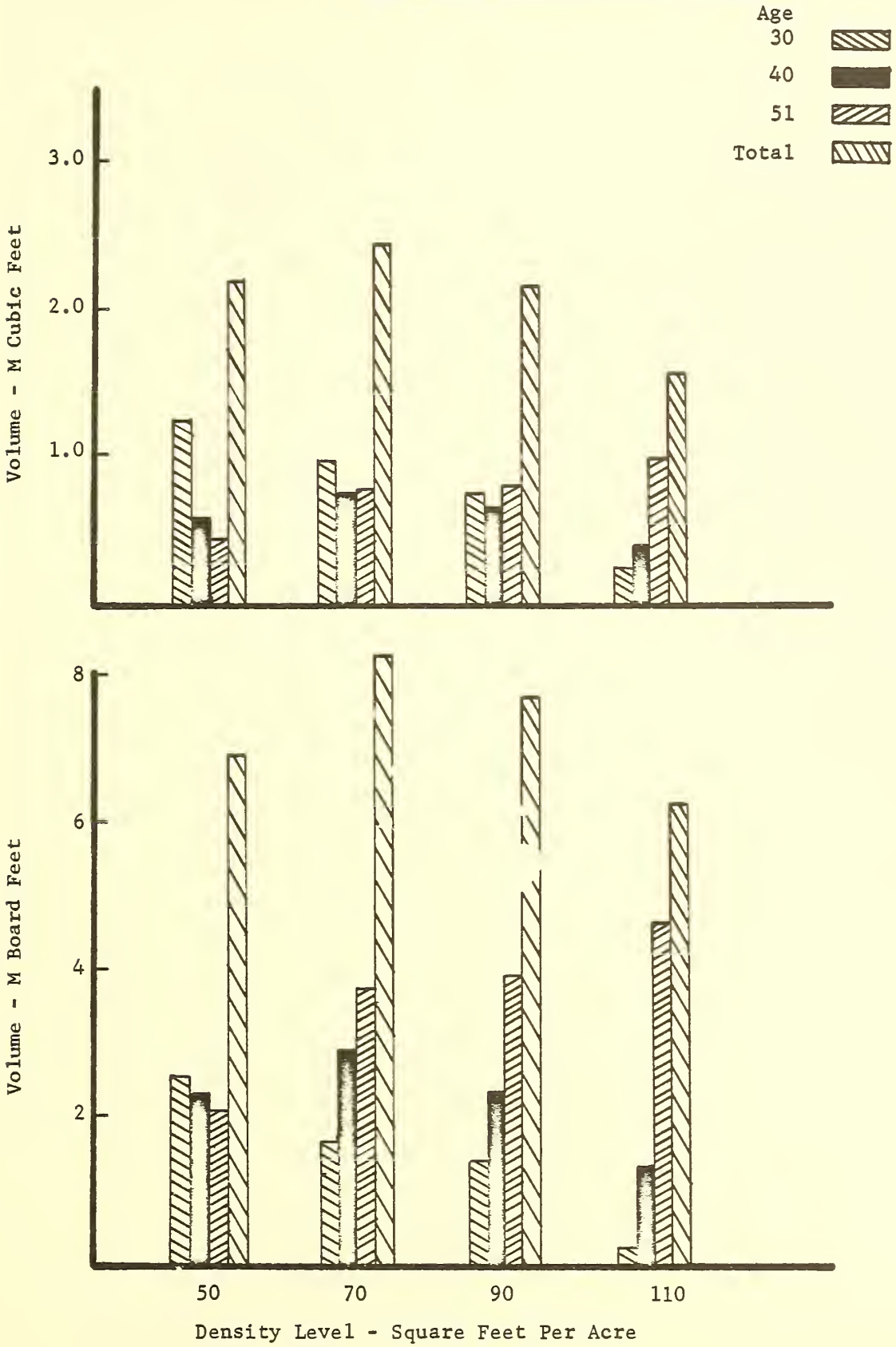


Figure 4.--Periodic annual growth per acre of shortleaf pine with and without hardwoods

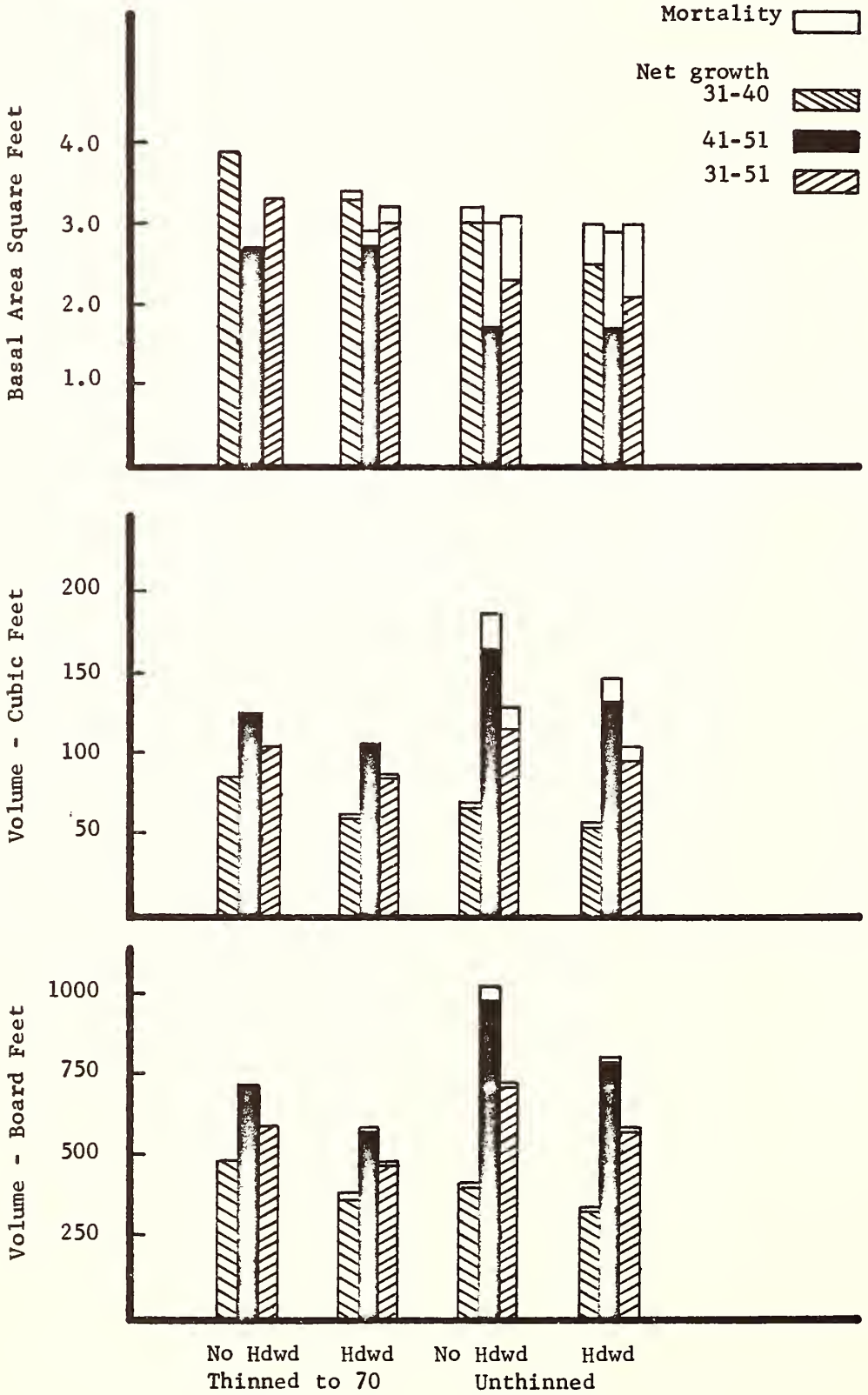
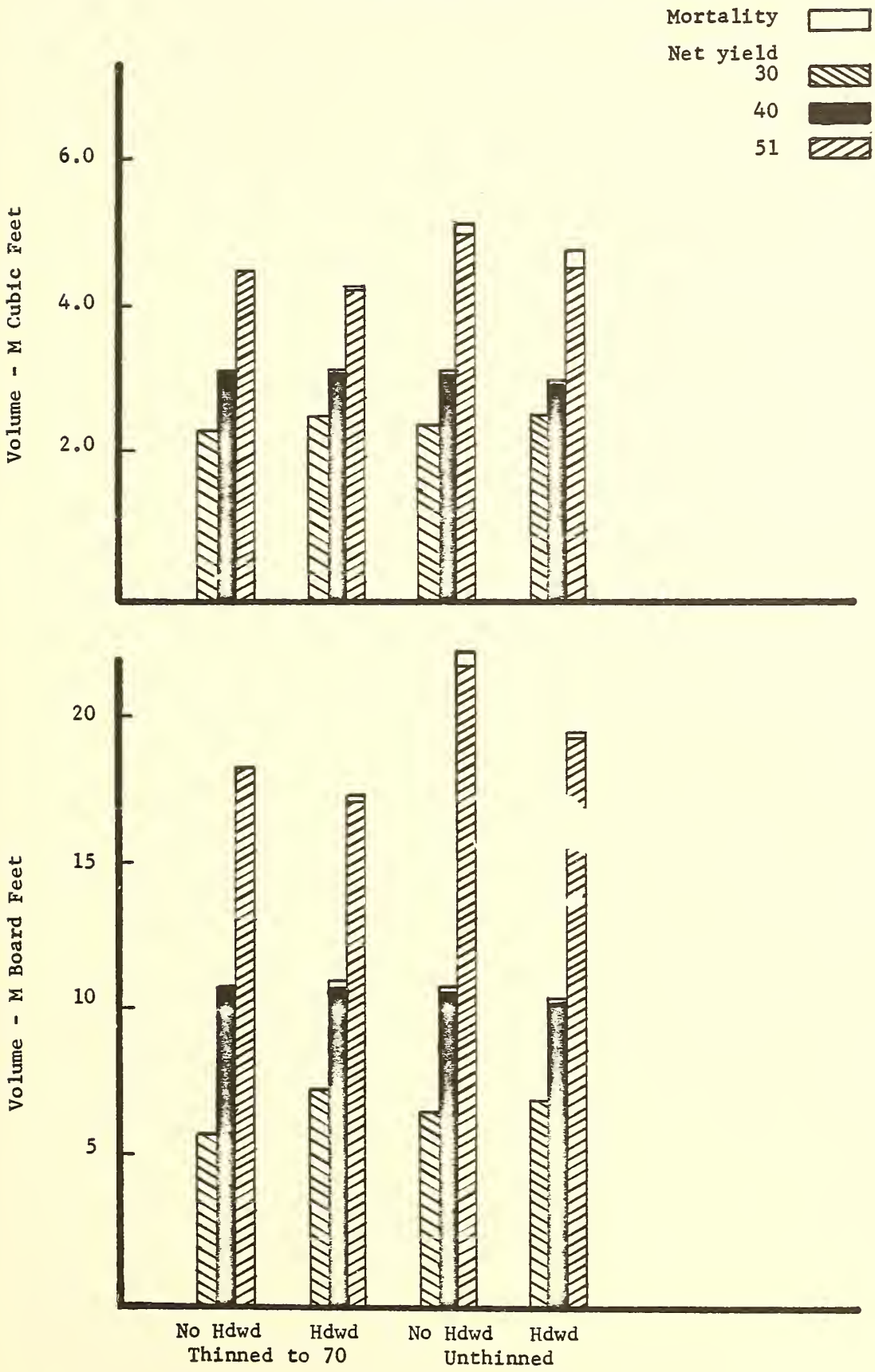


Figure 5.--Periodic yield per acre of shortleaf pine with and without hardwoods



GROWTH AND YIELD OF SHORTLEAF PINE PLANTATIONS

Glendon W. Smalley[1/]

Abstract.--This paper reviews mensurational characteristics of shortleaf pine plantations established on old-fields. Topics included are tree volume tables, site index curves, yield tables, stand structure, species comparisons, and response to thinning.

Additional keywords: Volume tables, site index, stand structure, thinning, species comparison, Pinus echinata.

INTRODUCTION

Published information about growth and yield of shortleaf pine (Pinus echinata Mill.) in plantations is limited both in quantity and coverage of the range of the species (Williston, 1975), and nearly all is concerned with plantations established on old-fields. I found one report dealing with cut-over sites (Wakeley, 1969), one on sites converted from mixed upland hardwoods (Loftus, 1974), and none on intensively prepared sites.

Growth and yield information about shortleaf pine plantations has been developed for four areas: 1) Piedmont, 2) Upper Coastal Plain and Loessial Hills in north Mississippi and west Tennessee, 3) southern Illinois and southern Indiana, and 4) the Interior Uplands of Tennessee, Alabama, and Georgia.

In this paper, I considered growth and yield in the broadest sense and included information about tree volume tables, site index curves, yield tables, species comparisons, and effects of thinning.

TREE VOLUME TABLES

Four volume tables have been developed specifically for shortleaf pine plantations on old-fields (Table 1). Tables for the Central States (Clark and Williams, 1958; Boggess and Olson, 1959) also apply to plantations established north of the natural range of the species. Gingrich (1962) expanded these tables to accommodate a variety of minimum top diameters, both fixed and variable.

Tables for the Tennessee River Valley (Potts, 1952) were based on both planted and natural stands, so Smalley and Bower's (1968) tables should be preferred for calculating cubic-foot volumes of old-field plantations in this area.

All tables were developed from equations based on the combined independent variable D^2H, where D is d.b.h. and H is total tree height. Details of

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Table 1.--Tree volume tables for shortleaf pines in plantations established on old-fields

Reference	Area	Volume Category[1/]
Potts (1952)	Tennessee River Valley	CVIB4INIB
		CVIB3INIB
		CVIB2INIB
		Number of Posts by Size Class
		BF5INIB
		BF6INIB
Clark and Williams (1958)	Central States	CVIBTOT
		CVIB3INIB
Boggess and Olson (1959)	Southern Illinois	CVIB3INIB
Smalley and Bower (1968)	Interior Uplands of Tennessee, Alabama, and Georgia	CVOBTOT
		CVIBTOT
		CVOB2INOB
		CVIB2INOB
		CVOB3INOB
		CVIB3INOB
		CVOB4INOB
		CVIB4INOB

1/ CV = cubic-foot volume; BF = board-foot volume, International ¼-inch kerf; OB = outside bark; IB = inside bark; TOT = entire stem; 2IN, 3IN, 4IN, 5IN, and 6IN = merchantable top diameters.

the development of weighted regressions for the Interior Uplands were reported by Smalley (1973).

For plantations outside these areas, tree volumes will have to be estimated from tables in Miscellaneous Publication No. 50 (U. S. For. Serv., 1929), but users are cautioned that these tables were developed from trees in pure even-aged stands of second-growth shortleaf pine.

SITE INDEX CURVES

Site index curves have been developed for southern Illinois and the Interior Uplands (Table 2). Both sets of curves are anamorphic and were developed from logarithm of height versus age regressions. In other parts of the natural range of the species, Coile and Schumacher's (1953) curves, developed for natural old-field stands in the Piedmont Plateau, and curves in Miscellaneous Publication No. 50 (U. S. For. Serv., 1929), developed for even-aged second-growth stands have been used extensively. Site index curves for shortleaf pine plantations in the Missouri Ozarks are being developed.[2/] Most of these plantations were established by underplanting and release, but some were on old-fields.

To my knowledge, no comparative site index studies that included plantation-grown shortleaf pine have been made. Also no soil-site index relations have been developed for old-field shortleaf plantations.

YIELD TABLES

Two growth and yield systems have been developed for shortleaf pine plantations on old-fields (Table 3).

For predicting pulpwood yields, Ralston and Korstian (1962) presented a system of equations based on variations in stocking, average stand diameter, and volume-basal area ratios developed from multiple regressions. This analytical system was intended to solve such growth and yield problems as 1) preparation of yield tables for well-stocked stands, 2) growth predictions for non-merchantable stands, 3) yield estimates for merchantable stands of variable density, and 4) growth projections for thinned stands. Although the system included graphical aids and computational procedures, it did not receive wide application perhaps because the equations were not solved and presented as yield tables or perhaps because 30 years was its base age for site index. A procedure was presented for predicting growth of thinned stands, but it was not supported by field tests. The system was superceded by the more versatile diameter distribution methods of yield table and stand structure analysis.

Smalley and Bailey (1974b) presented detailed schedules of trees per acre, basal area, mean tree height, and cubic-foot yields in eight volume categories by 1-inch diameter classes for all combinations of four site indices (30, 40, 50, and 60), seven ages from seed (10, 15, 20, 25, 30, 35, and 40 years), and six planting densities (750, 1,000, 1,250, 1,500, 1,750, and 2,000 trees per

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2/ David L. Graney. Personal communication. Southern Forest Experiment Station, U. S. Forest Service, Fayetteville, Arkansas.

Table 2.--Site index curves for shortleaf pines in plantations established on old-fields

Reference	Area	Specifications
Gilmore and Metcalf (1961)	Southern Illinois	Age: 13 to 35 years Height: 10 to 60 ft. Site index: 20 to 50 Base age: 25 years since planted
Smalley and Bower (1971)	Interior Uplands of Tenneseee, Alabama, and Georgia	Age: 10 to 40 years Height: 20 to 90 ft. Site index: 40 to 70 Base age: 25 years from seed

Table 3.--Yield tables for shortleaf pine plantations established on old-fields

Reference	Area	Components
Ralston and Korstian (1962)	Lower Piedmont of North Carolina	Height Number of trees per acre Average stand d.b.h. Volume per sq. ft. of basal area
Smalley and Bailey (1974b)	Interior Uplands of Tennessee, Alabama, and Georgia	Survival Diameter distribution Total tree height Site index Tree volumes

acre). These results depict the development of unthinned shortleaf pine plantations on old-fields throughout the Interior Uplands. Predictions were extended 5 years beyond the oldest sampled stands, and all relationships appeared biologically valid. Stand development can best be understood by plotting the various stand characteristics with respect to age, site index, and number of trees planted per acre. Figures 1, 2, 3, and 4 are examples of these plottings. A summary of trends follows.

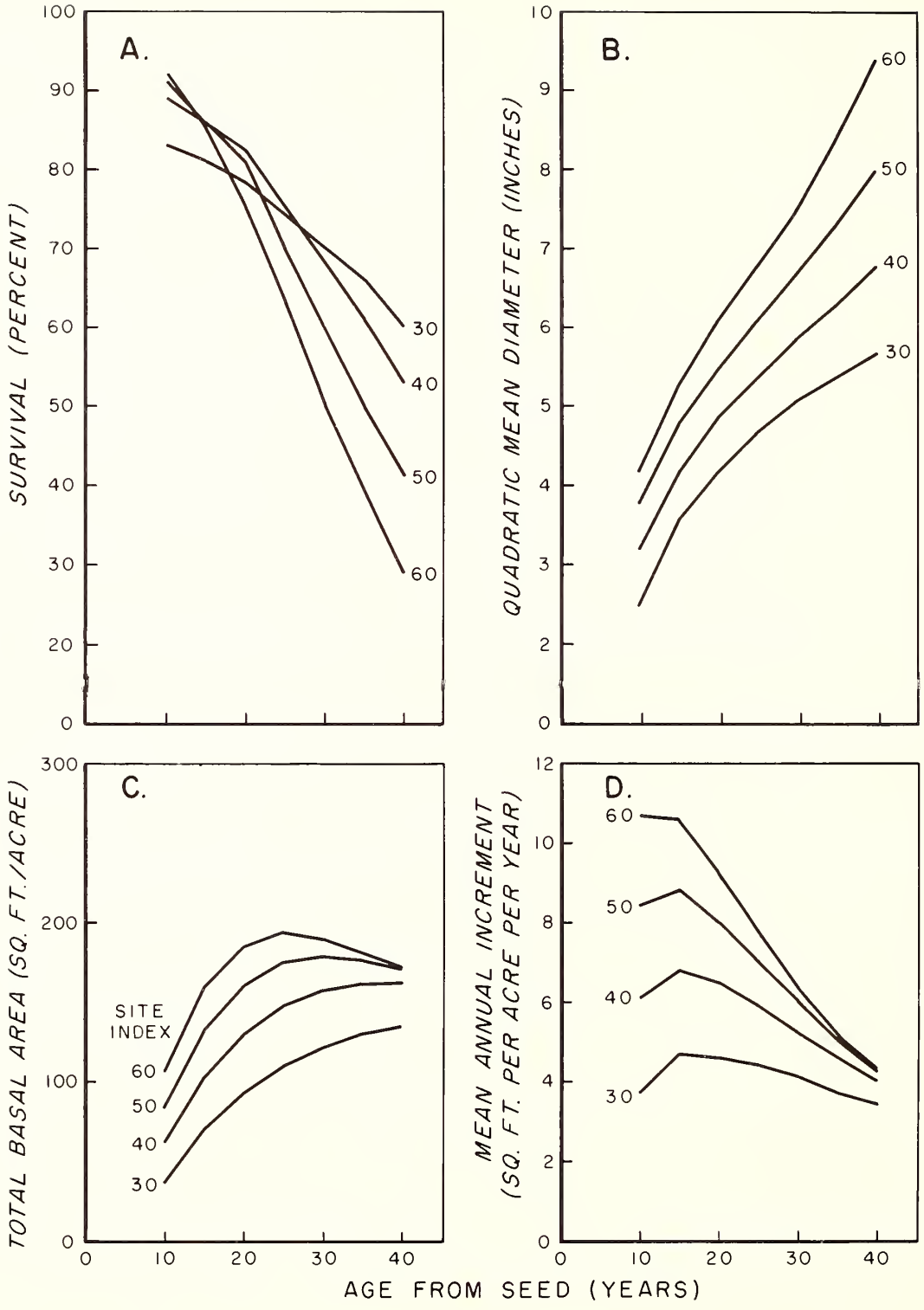

Figure 1.--Effect of age and site index on (A) survival, (B) quadratic mean diameter, (C) total basal area, and (D) mean annual increment - total basal area of shortleaf pine plantations at a planting density of 1,250 trees per acre.

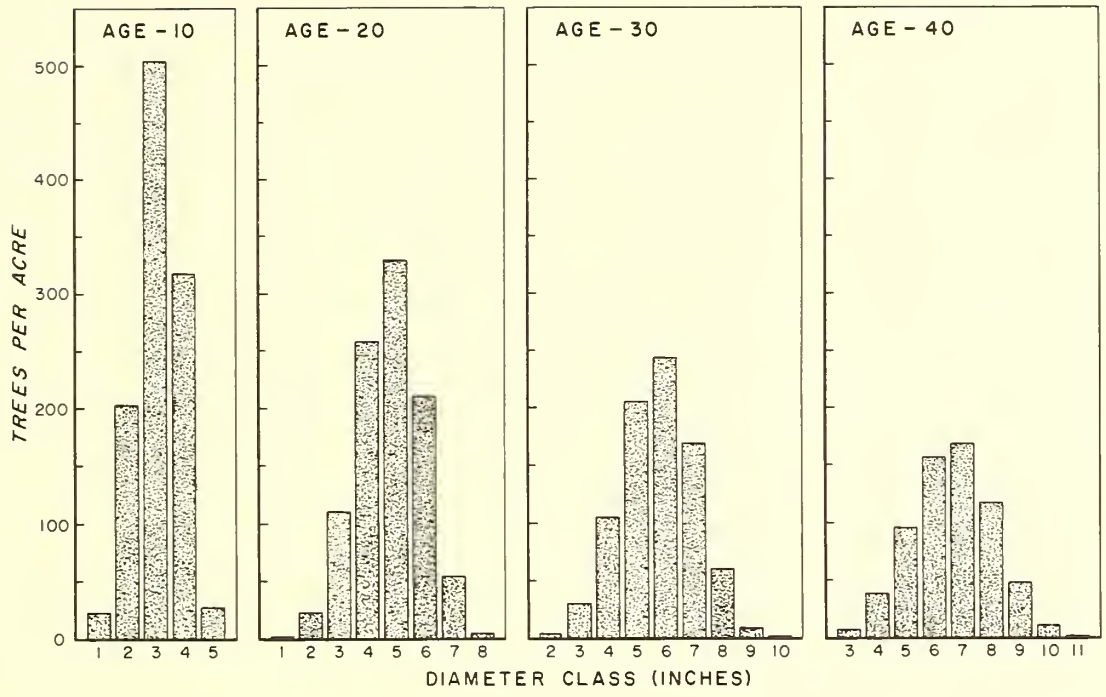

Figure 2.--Effect of age on diameter distribution of shortleaf pine plantations at a planting density of 1,250 trees per acre on site 40.

Survival.--On all sites, survival percentage decreased as planting density and age increased (Fig. 1A). With an increase in site index, however, survival was slightly better at early ages and, because competition intensified on better sites, worse at older ages.

Diameter distribution.--Diameter distributions (Fig. 2) form a bell-shaped curve the peak of which flattens and the width of which gradually widens with time. The largest diameter trees were on the best sites at the lowest planting density at age 40. Maximum size of trees decreased with an increase in planting density and a decrease in site. By age 25 some sawlog-size trees are obtained on the best sites even at a planting density of 2,000 trees per acre (equivalent to a spacing of 4 x 5 ft.). Very few trees reach sawlog-size in 40 years on poor sites.

Quadratic mean diameter.--As planting density increased, mean diameter declined for all ages and sites, but improvement in site always caused diameter increases (Fig. 1B). On sites 30 and 40 at all planting densities, diameter growth was nearly linear past age 20. On sites 50 and 60 at all planting densities, diameter growth accelerated slightly beyond age 20.

Basal area.--Total basal area (trees of all sizes) for sites 50 and 60 culminated before age 40 for all planting densities (Fig. 1C). On site 40,

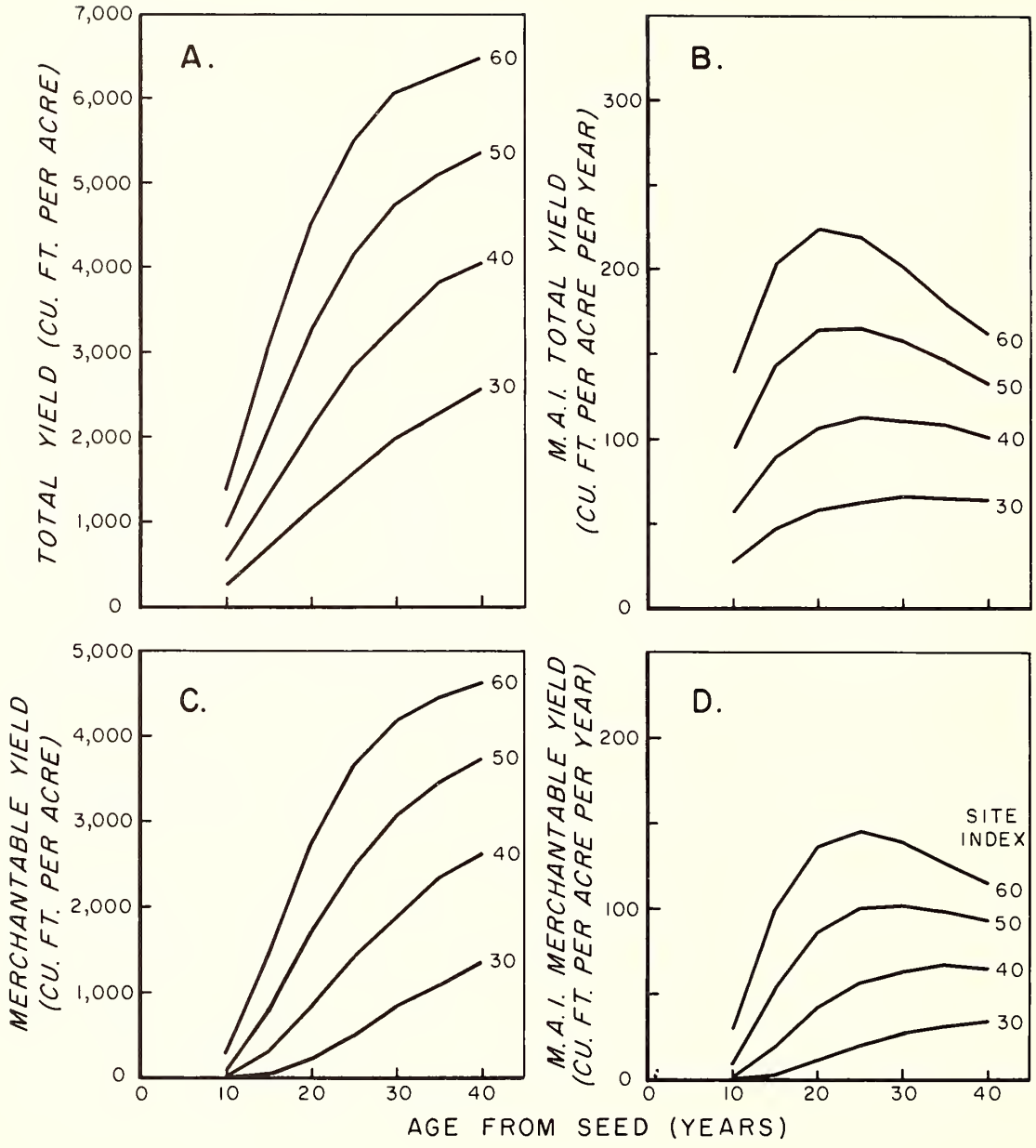

Figure 3.--Effect of age and planting density of (A) total yield - VOBTOT, (B) mean annual increment (MAI) - total yield, (C) merchantable yield - VIB4INOB, and (D) mean annual increment (MAI) - merchantable yield of shortleaf pine plantations at a planting density of 1,250 trees per acre.

culmination was at densities greater than 1,250 trees per acre. On poor sites culmination was projected at about age 50 for all planting densities except for 750 trees per acre where culmination will be closer to age 55.

Basal area increment.--For total basal area, mean annual increment (MAI) culminated by age 20 for all sites and planting densities (Fig. 1D). At low planting densities on best sites, MAI culminated before age 10. Increment at

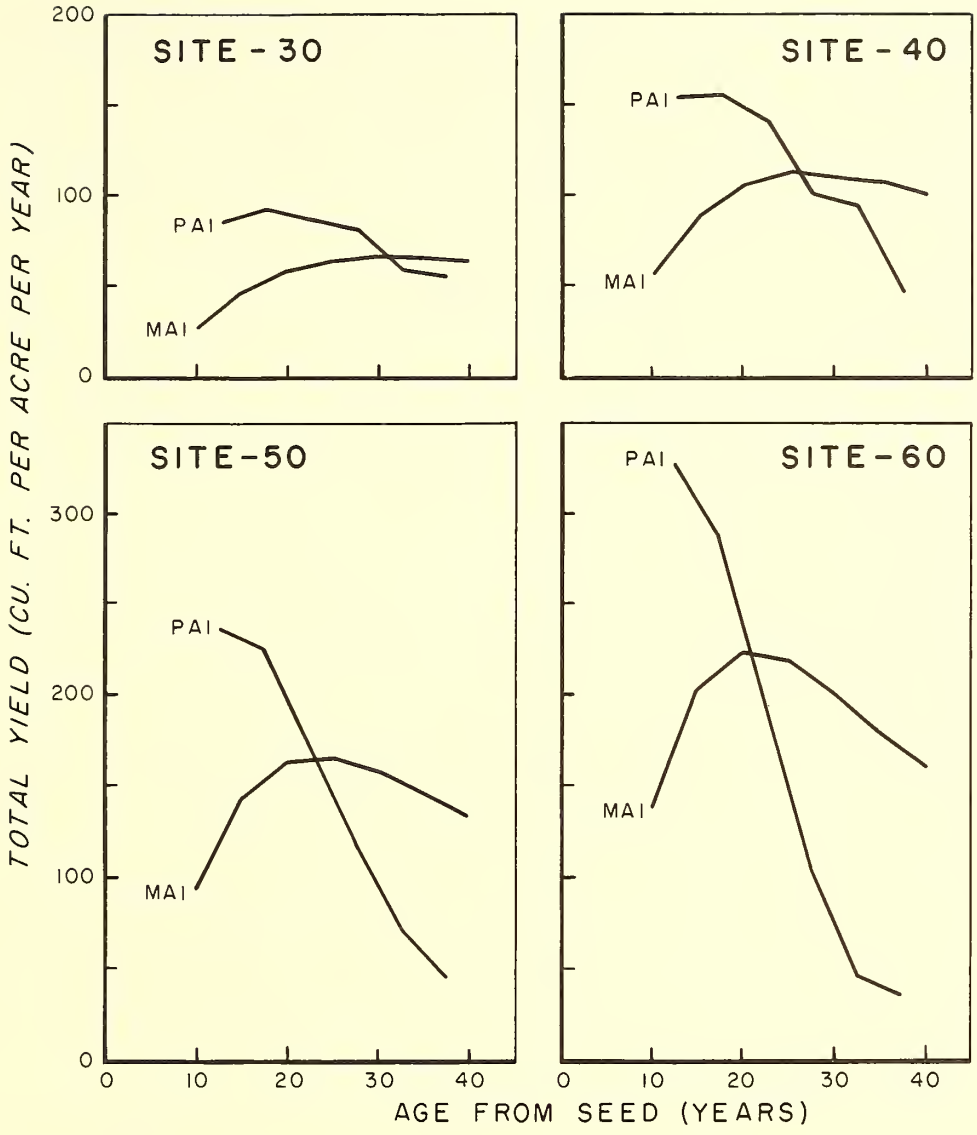

Figure 4.--Effect of age and site index on mean annual (MAI) and periodic annual increments (PAI) - total yield of shortleaf pine plantations at a planting density of 1,250 trees per acre.

culmination increased with planting density up to 2,000 trees per acre on all sites. All periodic annual increment (PAI) curves for total basal area were descending within the range of data.

Yield.--Total and merchantable cubic-foot yields increased with site and planting density, but effect of density was small on poor sites (Figs. 3A and 3C). Yield increased with age for all planting densities on sites 30, 40, and 50. For a planting density of 2,000 trees per acre on site 60, yield culminated at about age 35 as the loss of volume from mortality had begun to exceed growth on the remaining trees.

Yield increment.--For total volume, mean annual increment culminated for all sites and planting densities (Figs. 3B and 4). Age at culmination ranged from 30 years on poor sites to about 20 years on the best sites, regardless of planting density. Increment at culmination increased with planting density up to 2,000 trees per acre on all sites. By age 20, PAI culminated on sites 30 and 40 at all planting densities. All other PAI curves were descending within the range of data. Merchantable-volume increment culminated on sites 40, 50, and 60 at all planting densities (Fig. 3D), but at older ages than for total volume -- for example, age 35 to 40 for site 40 and age 25 for site 60.

SPECIES COMPARISONS

In the Ridge and Valley physiographic province in east Tennessee, the 20-year yield of shortleaf pine was more than the yield of white pine (Pinus strobus L.), and yellow-poplar (Liriodendron tulipifera L.) (Burton 1964) (Tables 4 and 5A). On the best sites, however yellow-poplar outgrew the pines. White pine had the greatest average d.b.h. and total height. Shortleaf pine's primacy in yield was due to its higher survival.

In the Virginia Piedmont, 16-year performance of loblolly (Pinus taeda L.) was slightly better than white pine and much better than that of either Virginia (Pinus virginiana Mill.) or shortleaf pine (Kormanik and Hoeskra, 1963). However, the poor performance of shortleaf and Virginia pine may be due to seed source.

In the South Carolina Piedmont, shortleaf pine growth was acceptable but much less than the growth of slash (Pinus elliotti Engelm.) or loblolly (Branan and Porterfield, 1971). Virginia, longleaf (Pinus palustris Mill.), and eastern white pine were not regarded as suitable for timber production.

In the Upper Coastal Plain of north Mississippi and west Tennessee, shortleaf did not grow as well as loblolly in two tests (Williston, 1958 and 1959) (Table 5B). The test in north Mississippi was on a good site while the one in west Tennessee was on a somewhat poorer site. In both cases, site index (base age 50) of shortleaf pine was 15 units less than the index of loblolly -- 98 versus 73 and 75 versus 60 -- at ages 23 and 29, respectively.

In another test in west Tennessee loblolly outgrew all other species in the first 5 years after outplanting (Snow, 1956). Total height of shortleaf was about two-thirds that of loblolly. White pine growth was poor and slash pine grew well though its survival was reduced by winterkill. All planted hardwoods grew much slower than loblolly, and Snow recommended that they be restricted to the bottoms.

Shortleaf pine is seldom damaged by snow and glaze; loblolly pine is more susceptible. Therefore, large-scale plantings of loblolly north of its native range should be undertaken with caution.

SPECIES-SPACING TRIALS

In the Georgia Piedmont, Jackson (1958) found that spacing appreciably affected survival and growth of 14-year-old shortleaf and loblolly pine (Table 6). Shortleaf grew 16 percent slower in diameter, 25 percent slower in basal area, and 46 percent slower in merchantable volume than loblolly. The 4 x 4

Table 4.--Studies comparing shortleaf pine with other species in plantations established on old-fields

Reference	Location	Comparative Species	Plantation age	Spacing
			Yrs.	Ft.
Burton (1964)	Norris Watershed, East Tennessee	White pine Yellow-poplar	20	6 x 6
Kormanik and Hoekstra (1963)	Virginia Piedmont	White pine Virginia pine Loblolly pine	16	6 x 6
Branan and Porterfield (1971)	South Carolina Piedmont	White pine Virginia pine Loblolly pine Slash pine Longleaf pine	13	8 x 8
Williston (1958)	North Mississippi	Loblolly pine	23	5 x 5
Williston (1959)	West Tennessee	Loblolly pine Slash pine Longleaf pine	29	6 x 6
Snow (1956)	West Tennessee	White pine Loblolly pine Slash pine Eastern redcedar Yellow-poplar Sweetgum White ash White oak	5	8 x 8

and 5 x 5 ft. spacings were not recommended for either species because of the small average d.b.h. and the large percentage of trees in the 2- and 3-inch classes. The 8 x 8 ft. spacing was not recommended because of poor wood quality resulting from large branches associated with retarded natural pruning. Also, the relatively few trees would reduce the yield of the first thinning. Jackson considered a 6 x 6 or possibly a 6 x 8 ft. spacing the best compromise from the standpoint of survival, growth, wood quality, and yield of pulpwood in the first thinning.

In southern Illinois, both shortleaf and loblolly grew satisfactorily for 20 years even though shortleaf was at the limit of and loblolly was beyond the natural range of the species (Gilmore and Gregory, 1974). Growth and yield of shortleaf was less than that of loblolly at all spacings. The greatest yield

Table 5.--Selected species comparisons in east and west Tennessee.

A. Norris Watershed in east Tennessee at age 20. From Burton (1964).

Species	Survival	Total height	D.b.h.	Basal area per acre[1/]	Volume per acre[2/]
	%	Ft.	In.	Sq. Ft.	Cu. Ft.
Shortleaf pine	57	39	5.3	127	860
White pine	44	42	5.7	125	759
Yellow-poplar	41	39	3.6	62	270

B. Upper Coastal Plain in west Tennessee at age 29. From Williston (1959).

Species	Survival	Average height of dominants	D.b.h.	Basal area per acre[1/]	Volume per acre[2/]
	%	Ft.	In.	Sq. Ft.	Cu. Ft.
Shortleaf pine	74	45	5.7	158	2,080
Loblolly pine	57	56	6.9	178	3,233
Slash pine	49	62	7.0	156	2,683
Longleaf pine	33	58	8.1	143	2,906

1/ All trees > 0.5 inch d.b.h.

2/ Inside bark, in trees > 4.5 inches d.b.h., to a 3-inch top inside bark.

of shortleaf was obtained at a spacing of 6 x 6 ft. For both species the 10 x 10 ft. spacing was too wide to produce optimal quantities of merchantable products at age 20.

The growth of unthinned shortleaf and loblolly pine plantations in the Interior Uplands can be compared by assuming that on similar sites, the site index (base age 25) of shortleaf will be 10 units less than the site index of loblolly (Smalley and Bailey, 1974a and 1974b). At all planting densities mortality takes a greater toll of loblolly than of shortleaf pine (Table 7). Through age 40 faster diameter growth of loblolly offsets its greater mortality, and loblolly plantations have greater basal areas and cubic-foot volumes than shortleaf plantations at all planting densities. However, both mean annual basal area increment and mean annual volume increment for loblolly decrease

Table 6.--Species-spacing trials involving shortleaf pine in plantations established on old-fields

Reference	Location	Comparative Species	Plantation Age	Spacing
			Yrs.	Ft.
Jackson (1958)	Georgia Piedmont	Loblolly pine	14	4 x 4 5 x 5 6 x 6 7 x 7 8 x 8
Gilmore and Gregory (1974)	Southern Illinois	Loblolly pine	20	4 x 4 6 x 6 8 x 8 10 x 10
Smalley and Bailey (1974a and 1974b)	Interior Uplands of Tennessee, Alabama, and Georgia	Loblolly pine	9, 19, 29, and 39	5 x 5 6 x 6 7 x 8

faster with age than do those of shortleaf pine, so that cubic-foot volume and basal area of shortleaf pine plantations may equal or exceed those of loblolly by age 55 or 60.

THINNING

Thinning experiments in old-field shortleaf pine plantations have been conducted in southern Illinois and southern Indiana, and the Upper Coastal Plain and Loessial Hills of north Mississippi (Table 8).

In southern Illinois, crown-thinning (thinning from above) on good and medium sites should probably be delayed until plantations are at least 20 years old (Boggess et al., 1963; Burkhart and Gilmore, 1967) (Fig. 5). Plantations on poor sites should be thinned 2 or 3 years earlier because net volume growth decreases sooner on poor sites than on good ones. This recommendation differs from the general consensus because thinnings on poor sites usually are delayed up to 10 years until tree diameters are large enough to support a commercial operation. Thinning should not be delayed much beyond age 25 on medium and good sites, particularly when planted at 6 x 6 ft. or closer spacings. Although shortleaf pine will grow and persist in dense stands, live crown ratios become so small that trees will not respond to release from thinning. About 40 percent of the basal area should be removed in the first crown-thinning.

Row thinning, which removed 25 percent of the basal area in the first thinning and 33 percent in a second thinning 4 years later, did not produce as much cubic-foot volume as crown-thinned or unthinned plots, although

Table 7.--Comparison of the effects of age and planting density on the per acre growth of shortleaf (SP) and loblolly pine (LP) plantations established on old-fields in the Interior Uplands. Site index (base age 25 years from seed) of shortleaf is 50 and loblolly is 60. From Smalley and Bailey (1974a and 1974b)

Age	Total number of trees		Number of trees > 9.5 inches d.b.h.		Quadratic mean diameter		Total basal area		Total volume (VOBTOT)		Merchantable volume (VIB4INOB)	
	SP	LP	SP	LP	SP	LP	SP	LP	SP	LP	SP	LP
yrs.					in.		sq. ft.		cu. ft.		cu. ft.	
PLANTING DENSITY - 750 TREES PER ACRE												
10	692	680	--	--	4.5	5.2	75	100	841	1,503	177	677
20	637	589	2	16	6.2	7.2	135	164	2,707	4,086	1,573	2,722
30	507	436	39	112	7.4	8.6	153	176	4,058	5,472	2,745	3,889
40	363	290	114	186	8.8	10.3	153	167	4,787	5,979	3,383	4,330
PLANTING DENSITY - 1,250 TREES PER ACRE												
10	1,097	1,061	--	--	3.8	4.4	84	113	945	1,697	90	528
20	960	860	--	1	5.5	6.4	161	195	3,275	4,858	1,712	3,109
30	726	596	11	55	6.7	7.9	179	202	4,733	6,418	3,077	4,511
40	493	371	75	176	8.0	9.5	170	182	5,326	6,523	3,721	4,705
PLANTING DENSITY - 1,750 TREES PER ACRE												
10	1,485	1,422	--	--	3.4	3.9	92	120	1,010	1,801	45	336
20	1,256	1,104	--	--	5.2	6.0	184	219	3,691	5,480	1,746	3,381
30	919	733	4	25	6.3	7.5	201	224	5,426	7,015	3,433	4.874
40	604	436	50	158	7.5	9.0	186	195	5,824	6,997	4,024	5,038

row-thinning did provide enough crop trees of good form and size (Gilmore and Boggess, 1969) (Fig. 5). Cubic-foot volume and volume growth rate were closely related to site quality because trees on good sites were taller and had more merchantable length. Stand density and site quality did not appreciably affect basal area growth.

In southern Indiana, Phipps (1973) concluded that free-thinning (removing trees in all crown classes) before age 30 was of questionable value in increasing growth and yield of stands planted at 6 x 6 ft. spacing. At age 32, after thinning to basal areas of 70 and 90 sq. ft. at ages 14 and 21, mean stand diameter had increased 1.9 and 1.0 inches, respectively, over unthinned stands, but merchantable yield was reduced 13 and 5 percent.

In a second test at age 29, after thinning to basal areas of 80 and 100 sq. ft. at ages 17 and 22, mean stand diameter had increased 0.7 and 0.2 inch, respectively, over unthinned stands, but merchantable yield was reduced 14 and 16 percent. Thinning lightly to 110 sq. ft. of basal area increased basal area growth rate and total yield. Thinning to 120 and 130 sq. ft. of basal area increased basal area growth rate, but total merchantable yield was about the same as that in unthinned stands.

Table 8.--Thinning studies in shortleaf pine plantations established on old-fields

Reference	Location	Thinning specifications	Plantation characteristics
Boggess et al. (1963)	Southern Illinois	Crown-thinned at ages 15 to 17 to basal areas of 60, 80, and 100 sq. ft. Final ages 20 to 22.	Good, medium and poor sites. Average height of dominant and codominant trees was 34, 29, and 24 ft., respectively. Basal area: 100 to 155 sq. ft. Stand volume: 1,200 to 2,400 cu. ft.
Burkhart and Gilmore (1967)	Southern Illinois	Crown-thinned at ages 13, 16, and 21 to basal areas of 70, 80, and 90 sq. ft. Final age 29.	Spacing: 8 x 8 ft. Average survival: 85 percent. Average basal area: 97 sq. ft. Average stand volume: 1,084 cu. ft.
Gilmore and Boggess (1969)	Southern Illinois	Row-thinned at age 14 removing 25 percent of basal area and at age 18 removing 33 percent of basal area; crown-thinned at age 23 to 80 sq. ft. Final age 30.	Spacing: 8 x 8 ft. Average survival 85 percent. Average basal area: 97 sq. ft. Average stand volume: 1,084 cu. ft.
Phipps (1973)	Southern Indiana	I. Thinned at ages 14 and 21, by removing trees in all crown classes, to basal areas of 80, 100, and 120 sq. ft. Final age 32. II. Thinned at ages 17 and 22, by removing trees in all crown classes, to basal areas of 70, 90, 110, and 130 sq. ft. Final age 29.	Spacing: 6 x 6 ft. Average survival 80 percent; Average basal area 127 sq. ft. Average site index (base age 25): 48. Average site index (base age 25): 48.
Williston & Dell (1974)	North Mississippi	Thinned at ages 17 to 29 in commercial operations.	Average site index: (base age 50): 31 to 82. Average basal area: 10-170 sq. ft.
Williston (In press)	North Mississippi	Thinned at ages 23, 28, and 32 to various basal areas according to 8 intensities. Final age 43.	Spacing: 6 x 6 ft. Average survival: 66 percent. Average basal area: 130 sq. ft. Average site index (base age 50): 71 to 80.

Because average tree height in both southern Indiana plantations was about 48 ft. at age 25, initial spacing seemed to be the major cause of differences between the Illinois and Indiana experiments. The 6 x 6 ft. Indiana plantations required nearly 30 years before they could support a commercial thinning while the 8 x 8 ft. Illinois plantations reached thinning age 5 to 10 years sooner.

In north Mississippi, 20-year growth resulting from seven thinning regimes applied to a 23-year-old shortleaf pine plantation was not significantly different and was not related to residual basal areas (Williston, 1978. Total merchantable yield was 4,122 cu. ft. on thinned plots and 3,685 cu. ft. on unthinned plots (Table 9). After the first thinning, thinned plots grew 2,583 cu. ft. and unthinned plots grew 2,235 cu. ft. -- a difference of 17.4 cu. ft. per acre per year. Periodic annual growth peaked at about age 35.

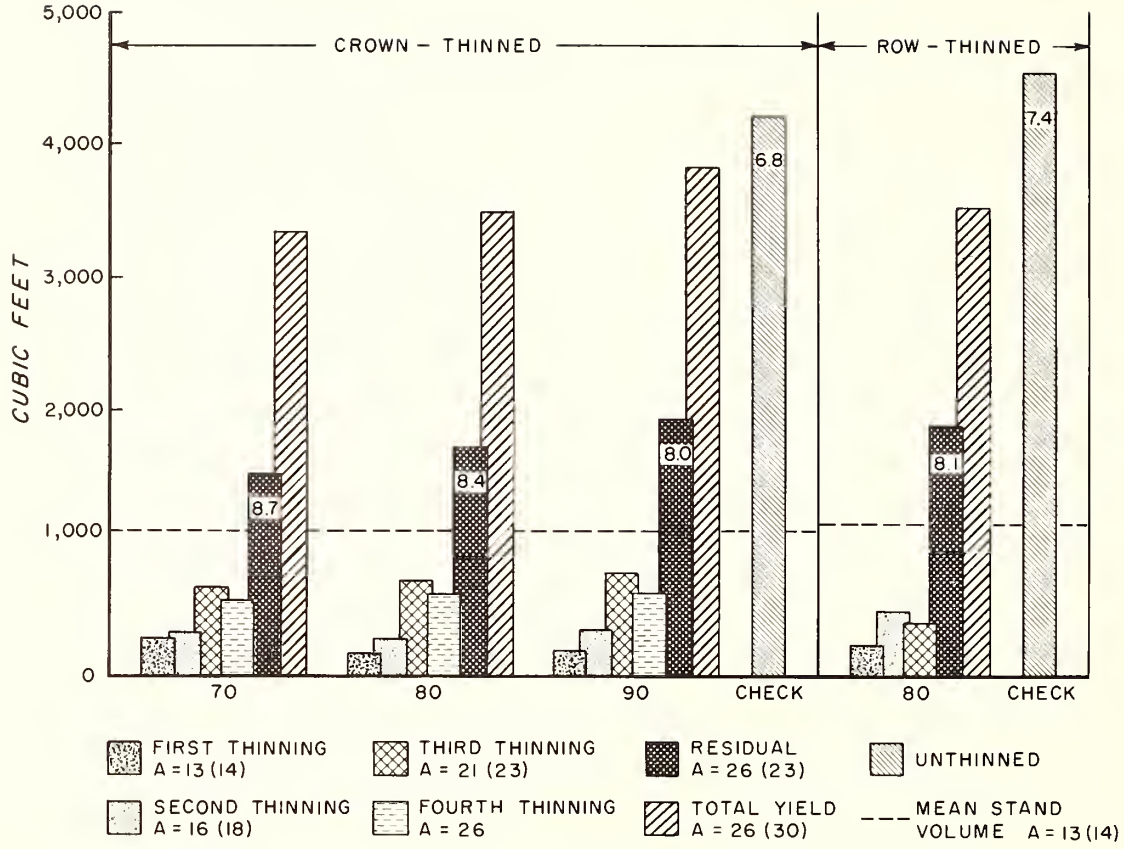

Figure 5.--Comparison of crown- and row-thinned shortleaf pine plantations established on old-fields in southern Illinois. Yield is expressed in merchantable cubic-foot volume inside bark, of trees > 3.5 inches d.b.h., to a 3-inch top inside bark. Numbers in the residual and control bars are mean stand diameters in inches. Ages in the legend are for the crown- and row-thinned experiments respectively. From Burkhart and Gilmore (1967) and Gilmore and Boggess (1969).

Mean annual growth of the thinned plots was 96 cu. ft. at age 43 and was leveling off. Mean annual increment of the unthinned plots was 86 cu. ft. When the plantation was first thinned at age 23, the average tree removed was only 5.4 inches d.b.h. Commercially thinning these plantations earlier would have been impossible without a good market for posts. A spacing of 8 x 8 ft. instead of 6 x 6 ft. would have permitted thinning at an earlier age and produced larger crop trees at rotation age. Even so, the sawtimber production of 13,070 bd. ft. per acre on the thinned plots at age 43 is impressive.

In determining pulpwood and sawtimber periodic growth rates for CCC plantings of shortleaf and loblolly pine in north Mississippi, Williston and Dell (1974) found that growth between ages 20 and 35 was increased by retaining high densities (Fig. 6). Thinning may reduce growth as well as increase the risk of losses to Fomes annosus (Fr.) Cke. Across the range of ages sampled,

Table 9.--Total and periodic yields from a thinned shortleaf pine plantation in north Mississippi. From Williston (In press)

Treatment	Unit[1/]	Period in years					Total yield
		0-23	24-28	29-33	34-38	35-43	
Thinned	Cu. ft.	67	105	121	155	135	4,122
Unthinned	Cu. ft.	63	118	81	169	77	3,685
Thinned	Fbm	--	38	240	850	1,390	13,070
Unthinned	Fbm	--	140	345	700	924	10,547

1/ Pulpwood volumes are in cubic feet inside bark, of trees >3.5 inches d.b.h., to a 3-inch top inside bark. Sawtimber volumes are in board feet, International ¼-inch kerf.

pulpwood growth rates for shortleaf pine increased with age while those for loblolly pine decreased with age. Shortleaf pine tolerates higher densities than loblolly.

Periodic annual increment for sawtimber relative to basal area culminated in nearly all situations for both species, because merchantability limits are more stringent for sawtimber than for pulpwood. Failure to thin dense stands reduced sawtimber growth rates within the span of ages encountered. The culmination pattern was more dramatic for shortleaf than for loblolly. For both species, culmination occurred at a higher basal area as site index increased.

In the Upper Coastal Plain and Loessial Hills of north Mississippi and west Tennessee, thinning has doubtful economic value when pulpwood is the major product, but if the owner insists on early returns, a single thinning is preferable to liquidation of the plantation. Commercial thinnings become feasible at age 20 to 25 for shortleaf and 15 to 20 for loblolly depending on site and planting density. Thinning should be primarily from below and about one-third of the basal area and up to one-half the trees will probably have to be removed to make the return attractive.

If growing sawtimber is the primary objective, basal area must be controlled by thinning. On shortleaf pine sites 60 to 90, thinning to basal areas equal to the site index is recommended at ages 25 to 30. Although loblolly pine is now regarded as more desirable than shortleaf for planting in north Mississippi and west Tennessee, owners should be cautious about liquidation and conversion to loblolly. Because shortleaf grows so well after age 20, landowners should consider holding these plantations until they at least reach small sawtimber size.

CONCLUSIONS

Within the common range of shortleaf and loblolly pine, old-field plantations of loblolly grow better than shortleaf plantations for 40 to 50 years. Beyond 50 years shortleaf yields apparently approach and perhaps exceed those

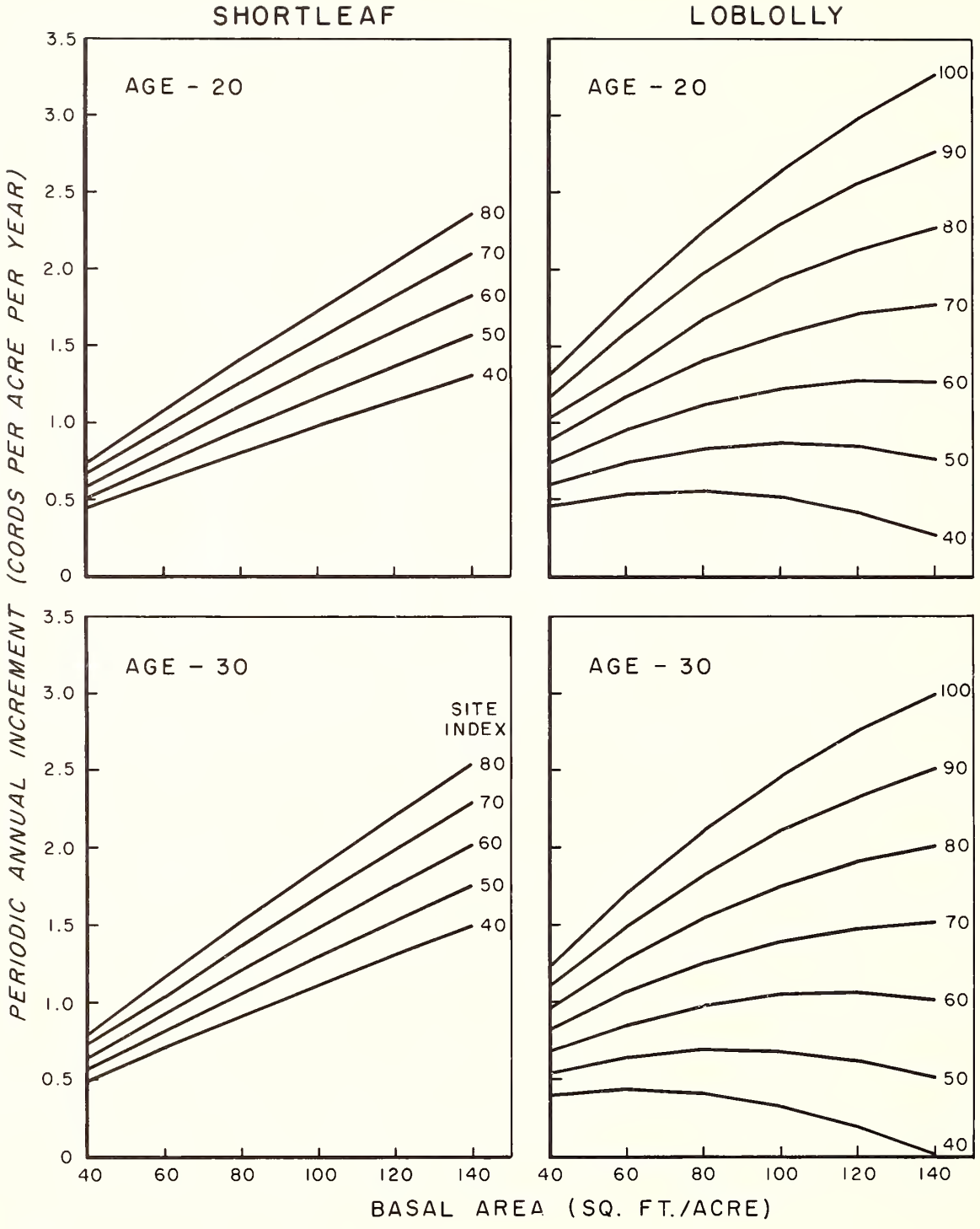

Figure 6.--Effect of age, basal area, and site index on periodic annual volume increment of CCC-established shortleaf and loblolly pine plantations on old-fields in north Mississippi. From Williston and Dell (1974).

of loblolly. Hence, loblolly is the preferred species when the management objective is pulpwood or short rotations. For longer rotations, shortleaf should be given equal consideration with loblolly. Outside the common range of shortleaf and loblolly pine, shortleaf should be preferred.

The acreage of shortleaf pine plantations established on old-fields is declining. Little agricultural land is being abandoned, practically none is being planted to shortleaf pine and owners are replanting harvested acres with faster-growing loblolly pine. Consequently, the available mensurational data seems adequate to manage this diminishing resource. A more urgent need is to develop multi-product, variable-density yield tables for both natural stands and those established by planting or seeding on prepared sites.

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GEOGRAPHIC SEED SOURCE AFFECTS PERFORMANCE OF PLANTED SHORTLEAF PINE

O. O. Wells[1/]

Abstract.--Selection of the proper seed source is essential in shortleaf pine, particularly if plantings are to be made in the northern part of the range where local seed sources should be used. In the central and southern parts of the range, longer seed movements can be safely made.

Additional key words: provenance tests, Pinus echinata

The latitudinal range of shortleaf pine is so great that if seed for planting stock is moved from the southern extremity of the natural range to the northern extremity (or vice versa) virtually complete failure can be assured. Within these latitudinal extremities, however, shortleaf seed can be moved long distances with little chance of maladaption and, in many instances, with very good chance of gain over more local stock.

Research to identify optimum seed collection and planting zones for the southern pines was begun in the mid-1950's. Sponsored by the Southern Forest Tree Improvement Committee, coordinated by P. C. Wakeley of the Southern Forest Experiment Station, and conducted by many public and private forestry organizations, a comprehensive seed source study of shortleaf pine was established as part of the Southwide Pine Seed Source Study (Wakeley, 1961).

In the series of tests reported here, 19 seed sources from throughout the natural range were collected, planted in 28 locations, and measured for 15 years. After that, measurements were suspended on several plantings because those remaining seemed adequate to determine if the patterns of variation that had appeared through the first 15 years would remain valid.

This network of seed sources and plantings has fulfilled several purposes so far. It has demonstrated that important variations due to seed source do exist in shortleaf pine, and that these variations are associated with climate at seed source and expressed to different degrees when planted in different climates. On the basis of these results, a map of seed collection and planting zones has been drawn.

METHODS

Seed was collected by cooperators in 1955 and the plantings established in winter 1956-57. Collection from at least 20 average-appearing trees at each geographic source was specified, and the seed gathered from all trees at any one source was mixed.

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The seed sources and plantings are divided into three series. Within each series all sources are represented in all plantings, and certain sources were included in two series to serve as a basis of comparison. This arrangement kept seed requirements and plantation sizes within manageable bounds and still provided most of the information that could have been derived from planting all sources at all locations. The series were designed to test specific hypotheses about the most probable causes of geographic variation, for example, the effect of latitude versus longitude. The three series were designated "Latitude," "Intermediate," and "Longitude." The design of each will be considered further as the results are presented. Each planting is a randomized, complete block design with four replications of six or seven seed sources. Forty-nine tree plots were used with two border rows surrounding each plot. Spacing was 6 x 6 feet.

Measurements of all plantations were made after the 3rd, 5th, 10th, and 15th growing seasons, and most plantings were measured after 20 years. Plot means were calculated and analysis of variance and multiple range tests performed at the 0.05 level of significance. The data were also subjected to analysis of variance that combined all plantings in one series.

The plantings within a series were then grouped by inspection, and the validity of the groupings tested by comparing the effect due to interaction of seed source and planting location with the effect due to seed source. When interaction was smaller than seed source effect, the grouping was accepted as valid; seed source means for the two or more plantings in each group were then subjected to multiple range tests. This procedure combined data from plantings where the rank order of the seed sources did not vary appreciably from planting to planting.

The only trait considered here will be volume per plot expressed in cubic feet. This value was calculated from the plot means for diameter, height, and the number of trees surviving. To make the data more realistic, we assumed a conic tree form. The data can be converted to approximate volumes per acre by correcting for plot size, which is .0405 acre.

RESULTS

Latitude Series

This series of seed sources and plantings samples the shortleaf range from near its southern extremity to near its northern extremity, a range of 14.2° F of mean annual temperature (Fig. 1). Sources and plantings are fairly evenly distributed over the entire range.

On the basis of 15-year total plot volume, the nine plantings were divisible into: a southern group of three plantings, an intermediate group of five plantings, and single plantings in Missouri and New Jersey.

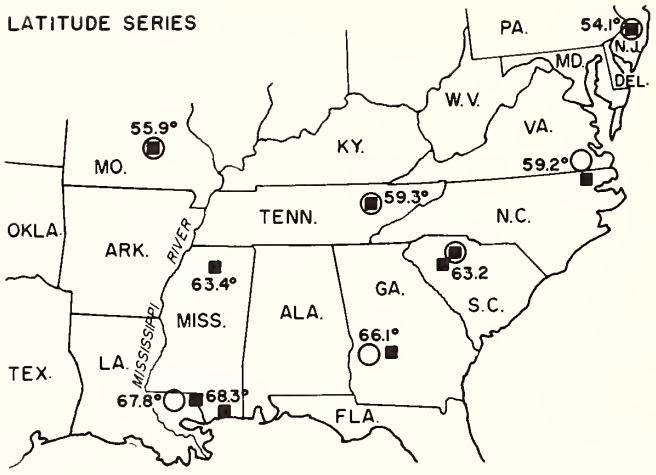

Figure 1.--Seed sources (circles) and plantings (black squares) of Latitude Series with mean annual temperature (°F).

In the southern plantings (southwest Georgia, south Mississippi, and southeast Louisiana--Fig. 1), differences among seed sources were distinct (Table 1).

Table 1.--Latitude Series. Plot volume in southern latitude plantings (southwest Georgia, south Mississippi, southeast Louisiana)

Seed Source[1/]	Plot Volume cu ft
Webster, (SW) GA	[2/]53.6 a
St. Helena, (SE) LA	51.6 a
Union, (W) SC	34.7 b
Dent, (S) MO	34.1 b
Anderson, (NE) TN	33.9 b
Southampton, (SE) VA	33.0 b
Burlington, (S) NJ	26.2 c

1/ County, (portion of state, SE = southeast, etc.) state

2/ Means followed by the same letter are not significantly different at the 0.05 percent level

The two sources of most southern origin--southeast Georgia and southeast Louisiana--were by far the best, and the New Jersey source was by far the worst. Seed sources from intermediate latitude (northeast Tennessee, west South Carolina, etc.) were intermediate in performance.

In the intermediate latitude plantings (west South Carolina, north Mississippi, northeast Tennessee, and northeast North Carolina), differences among seed sources were much less pronounced (Table 2). The difference between the best seed source

Table 2.--Latitude Series. Plot volume in intermediate latitude plantings (west South Carolina, north Mississippi, northeast Tennessee, northeast North Carolina

Seed Source[1/]	Plot Volume cu ft	
Webster, (SW) GA	[2/]60.2	a
Union, (W) SC	56.8	ba
Southampton, (SE) VA	54.8	ba
St. Helena, (SE) LA	51.3	cb
Anderson, (NE) TN	50.5	dcb
Dent, (S) MO	45.8	dc
Burlington, (S) NJ	44.7	d

1/ County, (portion of state, SE = southeast, etc.) state

2/ Means followed by the same letter are not significantly different at the 0.05 percent level

and the worst averaged 382.7 cu ft per acre in the four intermediate latitude plantings, whereas in the three southern plantings it was 679.0 cu ft. No seed source from any particular geographic area was outstandingly good or bad in the middle latitude plantings, but it is clear that one should not bring the most northern sources down to this latitude.

Farther north, however, climate separated the seed sources more distinctly and favored those of more northern origin. In the southern Missouri planting, the two most southern sources ranked last and had less than half the volume of the first-ranked New Jersey source, which had been last in the southern and intermediate plantings (Table 3). The climate in southern Missouri was not severe enough, however, to separate distinctly the seed sources from northern and intermediate latitudes. New Jersey and northeast Tennessee sources, for example, performed almost identically in the Missouri planting.

Table 3.--Latitude Series. Plot volume in southern Missouri planting (44)

Seed Source[1/]	Plot Volume cu ft	
Burlington, (S) NJ	[2/]31.8	a
Anderson, (NE) TN	31.5	a
Dent, (S) MO	27.2	a
Union, (W) SC	26.5	a
Southampton, (SE) VA	24.3	ba
St. Helena, (SE) LA	16.9	cb
Webster, (SW) GA	12.3	c

1/ County, (portion of state, SE = southeast, etc.) state

2/ Means followed by the same letter are not significantly different at the 0.05 percent level

In the northernmost planting (New Jersey), seed sources divided into three distinct groups on the basis of their latitude of origin (Table 4). The most local, New Jersey seed source, was by far the best in the New Jersey planting, attaining about twice the volume of intermediate latitude sources and 10 times the volume of southern latitude sources.[2/]

Table 4.--Latitude Series. Plot volume at 15 years in New Jersey planting

Seed Source[1/]	Plot Volume cu ft
Burlington, (S) NJ	[2/]50.9 a
Anderson, (NE) TN	27.6 b
Dent, (S) MO	25.6 b
Southampton, (SE) VA	21.8 b
Union, (W) SC	11.3 c
Webster, (SW) GA	5.1 c
St. Helena, (SE) LA	3.8 c

[1/] County, (portion of state, SE = southeast, etc.) state

[2/] Means followed by the same letter are not significantly different at the 0.05 percent level

Intermediate Series

Seed sources and plantings in this series are in three distinct geographic areas: west of the Mississippi River, the Piedmont and Cumberland Plateaus of Georgia and Tennessee, respectively, and the Ridge and Valley section of south-central Pennsylvania (Fig. 2).

For the Texas, Oklahoma, two southern Arkansas, and two central Georgia plantings, seed source x planting location interaction was small, so seed source means were calculated over all six of these plantings. These plantings formed a southern group in the Intermediate Series. Seed sources ranked similarly in the north Arkansas and northeast Tennessee plantings, so seed source means were calculated over these two plantings (intermediate latitude group). Because seed source performance in the Pennsylvania planting was unique, data from this planting were not combined with those from any other planting.

[2/] For a more detailed analysis of the New Jersey planting and the Pennsylvania planting of the Intermediate Series see Little, S. 1969. Local seed sources recommended for loblolly pine in Maryland and shortleaf pine in New Jersey and Pennsylvania. U.S. Dep. Agric. For. Serv. Res. Pap. NE-134, 16 p.

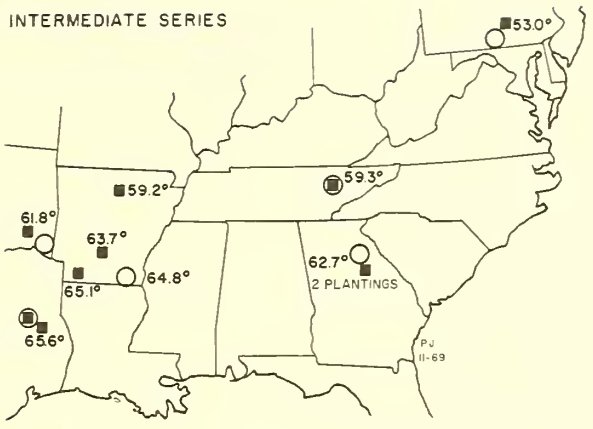

Figure 2.--Seed sources (circles) and plantings (black squares) of Intermediate Series with mean annual temperature (^{o}F).

In the southern group of plantings (Texas, Oklahoma, southern Arkansas, and Georgia) seed source differences were statistically significant, but geographic groups of seed sources (western, eastern, Pennsylvania) were not distinctly different from one another (Table 5). Western seed sources, however, ranked 1, 2, 3 in this group of plantings, ahead of the northeast Georgia and northeast Tennessee sources, so conservative judgment would be to favor western over eastern shortleaf, at least for planting west of the Mississippi River.

Table 5.--Intermediate Series. Plot volume in five western plus one Georgia planting

Seed Source[1/]	Plot Volume cu ft
Ashley, (SE) AR	[2/] 58.1 a
McCurtain, (SE) OK	54.3 ba
Cherokee, (E) TX	53.8 ba
Clarke, (NE) GA	44.9 cba
Anderson, (NE) TN	41.2 cb
Franklin, (S) PA	32.3 c

1/ County, (portion of state, SE = southeast, etc.) state

2/ Means followed by the same letter are not significantly different at the 0.05 percent level

In the intermediate latitude plantings (northern Arkansas and northeastern Tennessee) differences among seed sources were much smaller than in plantings further south (or north). The first- and last-ranked sources were separated by only 10 cu ft of volume per plot, a difference that was barely significant (Table 6).

Table 6.--Intermediate Series. Plot volume in middle latitude plantings (northern Arkansas and northeast Tennessee)

Seed Source[1/]	Plot Volume cu ft
McCurtain, (SE) OK	[2/]59.9 a
Clarke, (NE) GA	57.1 ba
Ashley, (SE) AR	57.0 ba
Anderson, (NE) TN	56.3 ba
Cherokee, (E) TX	54.6 ba
Franklin, (S) PA	49.7 b

1/ County, (portion of state, SE = southeast, etc.) state

2/ Means followed by the same letter are not significantly different at the 0.05 percent level

In Pennsylvania, differences among seed sources were distinct. As in the New Jersey Latitude Series, planting the most northern seed source gave by far the best results (Table 7). Survival and growth were poor for all seed sources in this planting, but the superiority of the most northern source was clear.

Table 7.--Intermediate Series. Plot volume in northern latitude planting (Pennsylvania)

Seed Source[1/]	Plot Volume cu ft
Franklin, (S) PA	[2/]10.5 a
Anderson, (NE) TN	3.9 b
Clarke, (NE) GA	1.8 b
McCurtain, (SE) OK	1.7 b
Ashley, (SE) AR	0.1 b
Cherokee, (E) TX	0.0 b

1/ County, (portion of state, SE = southeast, etc.) state

2/ Means followed by the same letter are not significantly different at the 0.05 percent level

Longitude Series

Seed sources and plantings range from South Carolina to Oklahoma in this series, but latitude is held constant (Fig. 3). Differences in plot volume were small and not statistically significant after 15 years in plantation (Table 8). The western sources rank 1,2, however, and this ranking taken with their good performance in the Intermediate Series seems good reason to favor them for planting, at least west of the Mississippi River. They would probably be satisfactory east of the Mississippi River as well.

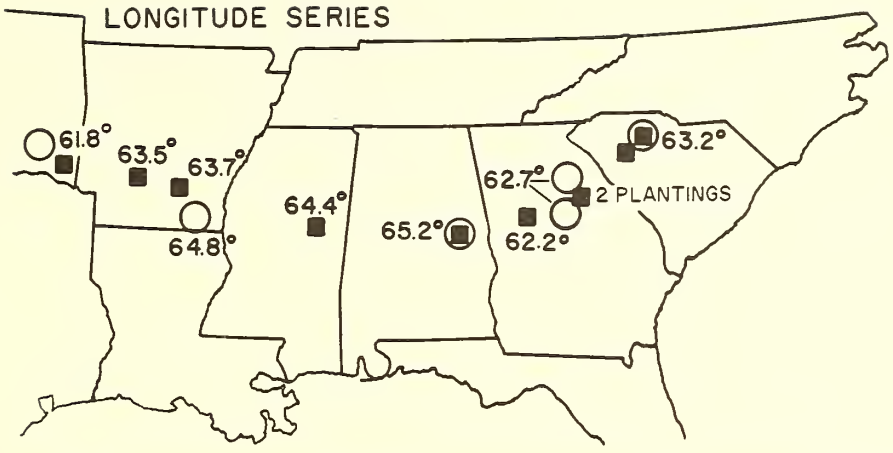

Figure 3.--Seed source (circles) and plantings (black squares) of Longitude Series with mean annual temperature (^{o}F).

Table 8.--Longitude Series. Plot volume at 15 years in eight plantings of similar latitude from South Carolina to Oklahoma

Seed Source[1/]	Plot Volume cu ft
Ashley, (SE) AR	[2/]65.4 a
Pushmataka, (SE) OK	65.1 a
Putnam, (N) GA	61.1 a
Union, (W) SC	60.1 a
Tallapoosa, (C) AL	59.7 a
Clarke, (NE) GA	58.0 a

[1/] County, (portion of state, SE = southeast, etc.) state

[2/] Means followed by the same letters are not significantly different at the 0.05 percent level

APPLICATION

Relative performance of these seed sources at 15 years was about the same as it was at 10 years (Wells and Wakeley, 1970), and the 20-year data from a sample of the plantings also indicate that no major changes have occurred. The basic patterns of variation became even more distinct between 10 and 15 years.

Therefore, the seed collection and planting zones mapped from the 10-year results still seem valid (Wells and Wakeley, 1970). The boundaries of the zones were located near test plantings and were extended into areas without plantings by following isotherms of mean annual temperature (Fig. 4).

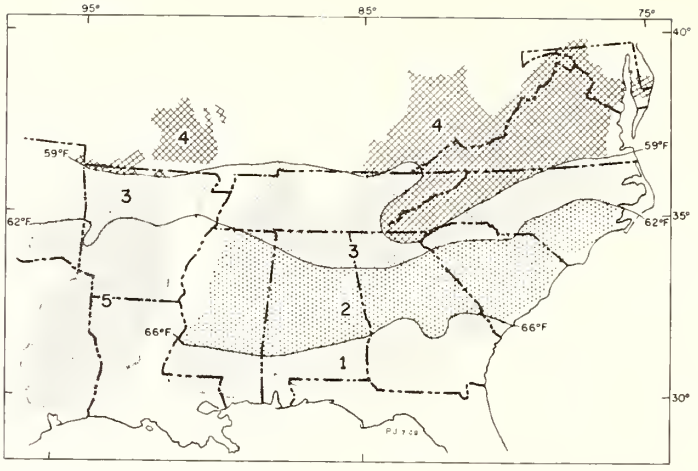

Figure 4.--Seed collection and planting zones for shortleaf pine.

In general, the zones are designed to take advantage of the major results of the study: (1) the tendency for trees from the two southernmost seed sources east of the Mississippi River to grow faster than those from northern sources in southern plantings and in plantings as far north as northern Mississippi, and (2) the superiority, in terms of both growth and survival, of trees from the most northern sources in the plantings near the northern extremities of the species range. In the middle of the range, on both sides of the Mississippi River, the relationship between growth in the test plantings and temperature at seed origin does not seem strong enough to limit seed movement.

Therefore, if shortleaf pine plantings are to be made in zones 1 or 2 (Fig. 4), seed should be collected in zone 1. Zone 5 seed would also be satisfactory for zones 1 and 2. Seed for planting in zone 5 should come only from zone 5. For planting in zone 3, seed can be collected in either zones 2 or 3 or in the northern half of zone 5. Seed for planting in zone 4 and beyond should be collected only in zone 4.

Seed orchards of selected phenotypes are rapidly becoming the primary source of seed for planting programs, but it would undoubtedly be wise to apply the same rules for seed movement of this seed as those for "wild" seed, at least until research shows that selected seed is more or less adaptable than "wild" seed. Fortunately, most seed orchards have their clones segregated into quite conservative geographic groups, so a mixture of seed with different potential for adaptation does not seem likely. Managers of orchards, nurseries, and planting programs need to be on their guard, however, that orchard seed or stock is not shipped too far simply because it is labeled "superior."

The 1974 Directory of Seed Orchards[3/] lists 471 acres of shortleaf seed orchards in the United States, with 391 acres belonging to the U.S. Forest Service. Two hundred and fifty acres are in a single Forest Service orchard near Mt. Ida, Arkansas. If there is a demand for it, perhaps distribution of surplus seed from these orchards could be negotiated with the Regional Forester.

3/ Forest tree seed orchards, a directory of tree seed orchards in the U.S. 1974. U.S. Dep. Agric. For. Serv., State and Priv. For., 33 p.

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MANAGEMENT OF EASTERN WHITE PINE IN THE SOUTH

by

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Abstract - While eastern white pine is generally viewed as a species limited to the Northeast, it is one of the most economically important species in the southern Appalachian Mountains. In the western North Carolina Blue Ridge range, in a belt between 1,000 and 2,500 feet elevation, white pine offers the best opportunity for intensive high-yield forest management. However, because of the limited range, the techniques of white pine regeneration have not received the attention that has been given the yellow pine. Crescent Land & Timber Corp., a wholly owned subsidiary of Duke Power Company, owns and manages some 270,000 acres in North and South Carolina of which approximately 40,000 acres are in the North Carolina white pine belt. For the past 18 years, that Company has been developing and applying intensive white pine management systems. This paper is intended to share some of the knowledge gained over this period of time.

In order to successfully regenerate white pine it is first necessary to understand that the species characteristics, and response to silvicultural treatment, are quite unlike those of the yellow pine. A regeneration system that has proven successful with yellow pine will not necessarily work, and probably will not work, with white pine. The reverse is also true. This is not to imply that white pine is more difficult to regenerate. On the contrary, in many cases it is easier and less costly (and a lot more fun, too). However, a greater understanding of the species and more finesse in the application of the system are required.

Silvicultural Characteristics

Listed below are a few of the silvicultural characteristics which are either unique to the species and/or which will dictate a different approach to regeneration techniques and systems:

1. White pine is semi-tolerant to shade.

2. Seed crops occur in 3 to 5 year cycles with heavy seeding in good seed years and no seed in intervening years.

3. Unlike yellow pine, bare mineral soil is not necessary for seed germination and survival.

4. Growth is slow for the first 3 years after planting; height at the end of the 3rd growing season ranges between 30 - 36 inches. Growth in the 4th season is between 3 and 4 feet with exceptional trees growing as much as 7 feet.

5. White pine will not naturally invade open land at elevation under about 3,000 feet.

6. Removal of the organic ground layer by mechanical site preparation greatly increases mortality of planted trees and reduces growth by as much as 50% during the first 4 years after planting. This effect ceases after the 4th growing season.

7. Response to release is quick and pronounced.

8. All terminal growth happens within a 30 day period between May 15 and June 15 and may exceed 2 inches per day during this period.

9. Herbicides will severely burn new growth if applied during the rapid growth period.

10. White pine is more sensitive than yellow pines to soil structural deficiencies such as poor drainage, hardpans, plasticity, etc.

Crescent's Regeneration System

Prior to 1960, Crescent attempted to manage its white pine lands on the all-aged, selection cut system. After some time, it became apparent that this was resulting in depleting the old stands without producing the required younger age groups. Had this system continued, the result would surely have been the creation of large acreage of brush land. In 1960, the Company's management decided that, if the land was to remain productive, the even-aged system would have to be adopted and capital input into regeneration would need to be increased. Several months of research into the available applied technology of white pine regeneration revealed that no regeneration technique was then available that would fulfill Crescent's needs. A new system would have to be developed. In the development of this system, certain limitations were recognized or self-imposed:

1. Costs per acre were to be no more than $30.00.

2. 600 to 1,000 acres were to be treated annually.

3. Except for temporary labor used for tree planting, all work would be handled by 2 regular employees utilizing no more than 75% of their available time.

4. Soil conservation was a high priority (Crescent's land constitutes the watersheds for Duke Power's hydro-reservoirs).

5. Natural regeneration did not appear to be a reliable possibility but would be used to the maximum when conditions were right and the technique was perfected.

In view of these limitations, it was obvious that intensive site preparation and individual stem treatment was out of the question. With the exception of tree planting, all treatments would have to be of a broadcast nature. In other words, this would be low horsepower forestry.

Because of white pine's semi-tolerance to shade, it was theorized that site preparation would be of no benefit on newly harvested land and that it might actually be harmful. This later proved to be correct. Also, because of the species characteristic of slow growth during the first 3 years after planting, it was believed that release from brush competition would be required in the 3rd, 4th, or 5th growing season. This also proved to be correct.

The technique which emerged was that of 1) clearcutting, 2) hand planting approximately 400 2-0 white pine per acre, followed by 3) herbicide release during the 3rd growing season. The release is accomplished by the application of 2 quarts of 2,4,5-T emulsified in 2 quarts of fuel oil and 4 gallons of water per acre. Application is normally by mist-blowers but the helicopter is sometimes used on rougher terrain.

During the early stages of the work, two rather severe problems quickly presented themselves: 1) severe herbicide burn to the current year's growth, and 2) pales weevil which dearly love to eat white pine and are capable of causing 100% mortality. Both problems were easily solved by changing the time of treatment. It was found that if application of the herbicide was delayed until after the rapid-growth stage (after June 15) the trees are almost completely immune to burn. It was also found that pales weevil were a problem only when planting followed too closely behind harvesting. By making May 1 the cutoff date for harvesting areas to be planted during the following winter, the weevil ceased to be a problem.

The technique is modified to treat specific conditions which differ from the average clearcut, as is the case with tracts that do not clean up well because of low merchantable volume and tracts that have heavy laurel and rhododendron. Such tracts are chemically treated between May 15 and June 15 with a mixture of one quart of Tordon 101, one quart of 2,4,5-T, one quart of fuel oil, and 17 quarts of water per acre. After a minimum of 45 days, the area may be burned if conditions warrant this extra step. Planting is done during the following winter. Herbicide release follows in the third growing season after planting. (There are two important precautions in using the modified system. First, the Tordon 101 must be the last ingredient to enter the solution after all other components are well mixed. Otherwise, the chemicals will "layer-out" and, as such, are worthless. Also, on burned land a large part of the insulating value of the organic layer is destroyed. This causes more frequent and severe freezing of the soil during the coldest part of the winter. For this reason, planting on burned land should be delayed until after February 1. Otherwise, winter drought conditions may cause high mortality of the planted trees.) Only five to ten percent of the total land area treated annually require the use of the modified system.

This regeneration system, along with the modified system, has now been applied to about 15,000 acres and continues at a rate of 800 acres per year. The results have been better than anticipated. Costs have risen during the 18 year period but not nearly to the extent that they have for those systems using mechanical site preparation. In 1977-1978, hand planting cost $26.00

per acre and chemical release cost $16.00 for a total of $42.00. The modified system costs about $63.00 per acre. However, when naturally regenerated areas, bearing a cost of only $16.00 per acre for chemical release, are averaged with artificially regenerated acreage, the average cost for all acreage treated is about $40.00.

Crescent's Natural Regeneration System

While the artificial regeneration system was being perfected and used, the basis for a natural system was falling into place. It had been originally assumed that since white pine will not naturally seed into open land at elevations under about 3,000 feet, regeneration by natural means would require some sort of partial cut which would provide shading. However, it was discovered by accident that seed in place at harvest will germinate and do quite well in logging debris. The exception to this is that during very hot and dry Junes, the newly established seedlings will sometimes perish on southern exposures.

Crescent's management plan calls for reserving the roughest tracts, having the highest potential planting costs, for harvest during years of heavy seed-fall. After the mid-August seed-fall, clearcutting begins and continues until seed germination in the following May. An inspection is made after frost to determine if spot planting is needed. The seedlings are released during the 4th year after germination by application of 2,4,5-T, as previously discussed.

The natural regeneration technique has now been used on some 2,500 acres with excellent results. It will continue to be used in any year in which seed are available.

Intermediate Age Management

Crescent's oldest woodland regenerated stands are now 17 years old. Therefore, the Company's experience in intermediate age management is limited.

The original plan was that the regenerated stands would be thinned for pulpwood at age 18, sawtimber thinned at age 26 and harvested at age 35. However, in the region surrounding Crescent's white pine lands, pulpwood prices have not kept pace with inflation. The economics of the first thinning are such that a negative stumpage price results. On the other hand, white pine sawtimber prices have risen by 350% in the past 18 years with most of the rise taking place in the past 6 years. This large change in product value relation has caused a rethinking of the original plan.

It is now believed that the best approach is to wait until the stands reach age 21 and make the first thinning for sawtimber. The lumber grade yield is actually higher from these small trees than for old growth trees. One of Crescent's stumpage buyers is now considering installing a high-speed gang mill to process these plantation logs.

The present tentative plan calls for age 21 thinning with a removal of 4,000 board feet, followed by another thinning at age 30 which should yield around 6,000 board feet. Final harvest is anticipated at age 40 with a yield of 16,000 board feet. This is equivalent to a growth yield conversion of about 1.7 cords/acre/year which is easily within the growth potential of white pine on average sites (Crescent's average site is 83 feet at age 50 base). If this projection proves correct, the total yield will be $3,120.00 at current stumpage prices and have a present worth, when discounted at 8%, of more than $260.00 per acre.

SPECIES-SITE SUITABILITY OF SHORTLEAF, WHITE, AND VIRGINIA PINES

John K. Francis[1/]

ABSTRACT.--Three important pines of the interior South, shortleaf, white, and Virginia pines, have somewhat different habitat requirements. This paper is a literature review of their natural range, growth rates, and edaphic and climatic requirements for establishment and growth.
Additional keywords: Soil-site studies, competition, climate, aspect, parent material.

Foresters often forget that a tree's reason for being is first to survive and secondly to reproduce. To do so, it must avoid the many hazards of the environment, it must gain a degree of dominance over competing vegetation, and it must develop the means for reproduction. While the production of wood products is incidental to the tree, we foresters attempt to match a species with sites where it will economically produce for us.

Three softwood species of the interior South--shortleaf pine, white pine, and Virginia pine--which are the subject of this symposium, produce valuable wood crops. Although they share many environmental requirements, each species reacts differently to the total environment, especially in extreme situations. First, I shall review and summarize the literature for each species with respect to environmental requirements. Then, I shall compare the response of the three species to varied environments.

Shortleaf Pine

Shortleaf (Pinus echinata Mill.) has the widest range of any southern pine. Its range extends from eastern Texas to Long Island, New York, and from southern Ohio to northern Florida. Natural stands occur from nearly sea level to 3,300 feet. Shortleaf grows naturally where mean annual temperature is 48° to 70° F, and rainfall varies from 40" to 55" per year (Fowells 1965). Fletcher and McDermott (1957) found that the northwestern extension of the shortleaf range depends upon a 17-inch minimum winter (November-April) precipitation. Shortleaf pine apparently cannot live in areas with annual rainfall less than 40" (Mohr 1896). Shortleaf is also reported to grow best with a high March to August rainfall (McClurkin and Covell 1965).

The wide natural range of shortleaf has produced considerable genetic variation. If this fact is not taken into consideration, experimental observations from widely separated areas may appear contradictory. Genetic variation

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also requires that one be cautious in planting shortleaf from a distant seed source.

Although shortleaf pine grows best on fertile north aspects and in minor stream bottoms, the species is generally found on dry, often rocky, ridges and south slopes (Racine 1966, Walker and Wiant 1966). Lower slopes are better than upper slopes (McClurkin and Covell 1965) and concave landforms are better than linear or convex landforms (Graney and Ferguson 1971). Della-Bianca and Olson (1961) found that shortleaf site index increased in the descent from ridgetop to stream bottom. Early survival of planted seedlings in eastern Tennessee was best on south slopes because there is less competition there (Minckler 1941). In these same plantations at 20 years old, survival was still the best on south slopes as was total volume. Height did not vary with aspect (Burton 1964).

Shortleaf occurs on soils derived from sandstone, cherty limestone, dolomite, limestone, and granite (Fletcher and McDermott 1957, Minckler 1946) and Coastal Plain sediments. Shortleaf is most often found on well-drained sites although its best growth occurs on soils with imperfect drainage (Fowells 1965). Shortleaf grows poorly both on excessively drained and poorly drained sites (Kormanik 1966). An adverse response to poor drainage may be the reason Della-Bianca and Olson (1961) found site index of shortleaf declined with increasing percent organic matter in the A1 horizon. However, Walker and Wiant (1966) reported that potted shortleaf could withstand flooding for up to 12 weeks.

Several workers found that growth of shortleaf increased as depth of the A horizon increased (McClurkin and Covell 1965, Dingle and Burns 1954). Minckler (1946), however, found little effect due to depth of the topsoil. Fowells (1965) stated that growth of shortleaf is best if there is 9 inches of topsoil or more. Coile (1935) found that 2 to 8 inches was best, and Zahner (1958) reported that growth increased with surface soil depth up to 20 inches.

There is general agreement that sandy loam topsoils are best for shortleaf (Allen,[2/] Fowells 1965, Racine 1966, Mohr 1896). Sands are a poor growth medium for shortleaf pine (Mohr 1896). Subsoil textures should be heavier than topsoils. Coile (1935) recommended that silt plus clay should exceed 60% of the soil composition in the B horizon. Others (Kormanik 1966, Walker and Wiant 1966) recommended sandy clay loam or clay loam subsoils. A high stone content in the B horizon is unfavorable (Graney and Ferguson 1971).

Nash (1963) maintained that soil moisture is the principal limiting factor for shortleaf in Missouri. This is probably true for most of the western portion of the shortleaf range and for shallow, sandy, or rocky areas elsewhere. Coile (1948) found that site index of shortleaf increased with the imbibitional water value of the subsoil in the North Carolina Piedmont.

[2/] Allen, J. C. Site index relationships of loblolly, shortleaf, and Virginia pines on the Cumberland Plateau and Sand Mountain. Unpubl. Prelim. Rep., Tennessee Valley Auth. Div. For. Release. 1961.

A friable subsoil is better for shortleaf than a plastic subsoil (Coile 1952, Fowells 1965, Turner 1938). Natural shortleaf usually occurs in areas with low pH (Racine 1966). Conversely, high pH can be detrimental to the species (Fowells 1965). Shortleaf is not usually found growing in soils with high Ca (Mohr 1896). Indeed, liming has been shown to reduce the growth of shortleaf in southern Illinois (Gilmore 1974).

Mohr (1896) and Turner (1938) believed that shortleaf was not sensitive to nutrient deficiencies. However, Walker and Wiant (1966) reported that shortleaf usually responded to nitrogen and occasionally to phosphorus.

Minckler (1946) found that 5-year-old plantations of shortleaf on old fields of Norris Lake Watershed in east Tennessee had grown as well on eroded areas as on uneroded areas. A Soil Conservation Service study, however, showed that eroded areas averaged 10 points lower in site index than uneroded areas (USDA-SCS 1957).

Shortleaf was the best pine for planting on strip-mined land in southern Illinois (Boyce and Neebe 1959). For planting in southern Ohio, Finn (1958) recommends moderately acid spoils. Limstrom (1960) observed better growth and survival on graded than ungraded spoils.

The incidence of littleleaf disease (Phytophthora cinnamomi Rands) is related to soil properties. The disease is associated with soils having poor internal drainage (Copeland 1949). Zak (1961) found that excessive water in the root zone was the principal antagonizing property rather than low oxygen.

White Pine

Eastern white pine (Pinus strobus L.) is basically a northern species. Its range surrounds the Great Lakes, covers the northeastern United States, and extends south along the cool, moist Cumberland-Appalachian systems into eastern Tennessee, western North Carolina, and north Georgia.

In the southern portion of its range, white pine grows at 2,000 to 4,000 feet (Walker 1967). Farther north, it grows at lower elevations. Abundant precipitation, especially during the warm season, is necessary for best growth. Across the range of white pine, precipitation varies from 20 inches in northern Minnesota to 80 inches in north Georgia (Fowells 1965). Fowells (1965) reports mean July temperatures of 62° to 72° F as necessary for white pine. In Tennessee and North Carolina, however, the range of white pine terminates between the 76° and 78° mean July isotherms (USDA 1941).

In the northern part of its range, white pine grows best on south and west aspects (Hannah 1971). In the southern states, it does best on north and east aspects (Walker 1967). Minckler (1946) reported high seedling mortality when white pine was planted on southerly aspects in eastern Tennessee.

White pine grows on practically all types of parent material within its natural range (Fowells 1965). Walker (1967) mentions schist, gneiss, and granite as important parent materials. Minckler's Norris Watershed plantations of white pine had better volume and height at 20 years on soils derived from limestone and dolomite than from shale (Burton 1964).

In the southern part of its range, white pine grows best on imperfectly drained soils, along rivers and streams. White pine grows somewhat more slowly on well-drained sites but still competes successfully with Virginia and pitch pines (Walker 1967). Planted white pine in Ohio and Indiana grew progressively better as soil texture became coarser (Gaiser and Merz 1953). Fowells (1965) found that site index increased as soil texture became coarser. In neither of the preceding cases, however, were the soils very sandy. Asahi (1953) reported that white pine was suitable for planting on most soils except very clayey ones. Gaiser and Merz (1953) also found that growth increased as moisture equivalent and wilting point decreased. Fowells (1965) found similar trends with site index. Growth of white pine decreased with increased plasticity and density of the subsoil (Fowells 1965, Minckler 1946).

In New England, growth of white pine increased with increased pH in the B and C horizons (Mader 1976). Also, Stratton and Struchtemeyer (1968) found that height growth increased with increased pH. Mader (1976) found that better sites for white pine had more soil N and more organic matter in the B horizons than poor sites. He also found that increased organic matter in the A horizon reduced site quality, which raises the suspicion that white pine responds differently in New England than farther south. In Japan, Ca saturation of 25% was optimum and 80% was the upper limit for growth (Asahi 1953).

The consensus of several authors (Gaiser and Merz 1953, Minckler 1941, Fowells 1965) is that white pine growth increases with increased thickness of the topsoil.

White pine has been tried for coal strip mine reclamation. While it is not the most aggressive species in colonizing and stabilizing mine spoils in West Virginia, in many cases white pine may offer the best chance of eventually producing sawlogs. Spoils with pH's of less than 4.0 should be avoided (Brown 1962). On the other hand, experience with white pine on coal spoils in Illinois leads Boyce and Neebe (1959) to doubt that white pine there would ever reach merchantability. Finn (1958) stated that white pine in Ohio does not do well on fine-textured, calcareous spoil bank material.

Virginia Pine

The natural range of Virginia pine (Pinus virginiana Mill.) extends between the Mississippi River and the Atlantic Ocean. Its northern boundary coincides with that of shortleaf pine. The southern boundary extends only a little way into South Carolina and Georgia, but somewhat further into Alabama.

Virginia pine grows from 100 to 2,500 feet above sea level. Fowells (1965) reported that annual precipitation varies from 35 to 50 inches within the botanical range of Virginia pine. I believe we should add at least 10 inches to the upper end of the scale. Range of frost-free days is 160 to 225.

Virginia pine grows best on north- and east-facing slopes but is more often found on ridgetops and south- and west-facing slopes (Slocum and Miller 1953). The species occurs on crystalline rocks, sandstone, shale and, to a lesser extent, limestone (Fowells 1965). Virginia pine, which is normally found on shallow or exposed soils (Olson and Della-Bianca 1959), will not tolerate very poor drainage (Fenton and Bond 1964, Fowells 1965).

Fowells (1965) reports that Virginia pine grows best on clay, loam, or sandy loam soils but poorly on shaly or very sandy soils. Sandy clay or silty clay subsoils are the most favorable to Virginia pine (Fenton and Bond 1964). Kormanik (1966) found increased growth with decreased 1/3 bar moisture holding capacity in the A2 horizon.

Natural Virginia pine grows best on soils from pH 4.6 to 7.9. Virginia pine commonly grows on old fields with low to medium levels of Ca, P, K, and organic matter (Slocum and Miller 1953). Fowells and Krauss (1959), working with Virginia pine seedlings in sand culture, found that the culture solution should contain from 25 to 100 ppm soluble N and at least 1 ppm P. They also found that Virginia pine could withstand 250 ppm Na without damage.

Virginia pine very often grows on eroded soils (Fowells 1965). Site index will be lower on old fields recently removed from cultivation or severely eroded than on virgin forest soils nearby (Slocum and Miller 1953). Virginia pine is a good species for strip mine reclamation, combining the features of hardiness, rapid growth, and good wildlife cover (Boyce and Neebe 1959). Lorio and Gatherum (1965) observed that survival of Virginia pine on spoil banks was associated positively with cation exchange capacity and associated negatively with soluble salts and nitrifiable N.

Comparisons

Shortleaf pine produces excellent sawlogs as well as posts, poles, and pulpwood. On sites where they both occur, shortleaf averages a lower site index than Virginia pine (Doolittle 1958, Olson and Della-Bianca 1959), but shortleaf grows steadily and lives longer.

Through middle Tennessee, shortleaf site indexes on dry sites range from 45 to 70 feet. Site indexes of nearly level to gently sloping upland sites range from 50 to 75 feet. On deep, medium-textured soils of north slopes and minor bottoms, shortleaf site indexes range from 60 to 85 feet (USDA-SCS 1969a, USDA-SCS 1969b). West of the Mississippi River, average site index of shortleaf pine will be about 5 feet less (USDA-SCS 1968).

Shortleaf pine is adapted to sites too infertile, dry, and warm for white pine. Shortleaf withstands ice, cold damage, and drought better than loblolly pine, which is often used to replace shortleaf. Shortleaf is thus more suitable to plant at higher elevations and farther north and west than loblolly. Shortleaf cannot survive or compete on many of the droughty and infertile sites inhabited by Virginia pine.

At higher elevations (perhaps 2,500 feet), shortleaf should be planted only on warm exposures. Planting shortleaf many miles north of its natural range is risky. In the southern part of its range, shortleaf has largely been displaced by loblolly except on severe sites or where markets exist for specialty products such as poles.

On favorable sites within its range, white pine outgrows all other conifers both in height and volume. White pine will outgrow the oaks through a wide range of sites and will outgrow yellow-poplar up to site index 95 for both species (Doolittle 1958). In coves and on toe slopes and moderately

well-drained floodplains on the Cumberland Plateau, the Appalachian Valley and Mountains, white pine site index ranges from 85 to 95 feet. Upland soils with adequate moisture holding capacity and moderate slopes have white pine site indexes of 75 to 85, while shallow, rocky, and steep soils may have site indexes of only 55 to 75 feet (USDA-SCS 1969a).

Natural stands of white pine are confined to cool moist areas, which usually mean higher elevations in the interior South. Yet white pine has done very well in Tennessee and other states somewhat removed by elevation and distance from its natural range. However, white pine cannot be expected to prosper in the summer droughts and high temperatures found in the southern areas west of the Mississippi River or on the Coastal Plain.

White pine in the southern states has been relatively free of disease and pests. It has a remarkable ability to shade out understory competitors. Also, it responds to release after persisting in a hardwood understory for many years.

Within its natural range, white pine can be planted or managed on all but the most exposed, rocky, or droughty sites, and very wet areas. We know little of its fertility requirements, but white pine has the reputation of being more nutrient-demanding than shortleaf or Virginia pines and less demanding than yellow-poplar. Survival and growth are probably best on medium-textured soils. Soil texture can be heavy on exposed sites and coarse on moister sites. Eroded areas and depleted old fields generally should not be planted to white pine.

Virginia pine produces an excellent pulpwood. It can also be used for sawlogs and posts. The principal difficulties in its harvesting and utilization are poor form and persistent limbs. The best attribute of Virginia pine is its ability to produce impressive yields on sites where most other species have difficulty just surviving. I have seen Virginia pine with 16-foot sawlogs growing on soil less than 8 inches deep.

In middle and eastern Tennessee, Virginia pine on shallow, rocky, steep, or eroded soils ranges in site index from 45 to 75 feet. Site indexes of level to moderately sloping upland soils more than 20 inches deep range from 50 to 85. On lower slopes and in coves and minor stream bottoms, site index of Virginia pine ranges from 65 to 85 (USDA-SCS 1969a, USDA-SCS 1969b).

Virginia pine is not exacting in its requirements for nutrients or soil physical properties, though better growth can be obtained with abundant nutrients and well-structured, medium- to slightly heavy-textured, and moist soils. Areas with impeded drainage should not be planted to or managed for Virginia pine.

Shallow or rocky ridges and exposed south slopes are excellent areas to plant or encourage Virginia pine. Formerly burned or logged areas with low fertility and eroded old fields support many of our present stands of Virginia pine. Most of these areas will revert to other species in one or two generations unless interfered with (McCormick and Andresen 1963).

I found little information about growing Virginia pine in the highlands west of the Mississippi River. Its drought tolerance and similarity to

shortleaf in natural range indicate that this species could be planted in Missouri and Arkansas.

Three conifers, each with different requirements, present foresters with options for management of many sites in the interior South. Shortleaf takes advantage of disturbance to establish itself across a broad range of sites in the eastern United States. White pine competes successfully with hardwoods in cooler mountainous areas. Finally, Virginia pine grows much better than white or shortleaf on adverse sites.

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GROWTH AND YIELD OF WHITE PINE

Donald E. Beck

Abstract.--Eastern white pine is one of the fastest growing species in the interior South. It commonly outgrows associated species in height, diameter, and volume across a wide range of sites. Plantation growth and yield are strongly influenced by initial spacing. Board-foot growth and yield and mean diameter growth are maximized at spacings of 12 by 12 feet or slightly greater. At that spacing average sites can produce 600-700 board feet per acre per year on a 35-year rotation. Both plantations and natural stands will apparently respond to thinning. But data are not sufficient to recommend thinning regimes.

Introduction

In the southern part of its range white pine exhibits remarkable traits, including relative freedom from the insects and diseases which plague it in the Northeastern United States. Most impressive, probably, is its remarkable rate of growth in comparison with other pine and hardwood species of the region. Doolittle (1958) found that white pine has the greatest rate of height growth and thus the highest site index of 10 species common to the Southern Appalachians on all sites except the very best where yellow-poplar is superior (Figure 1). Rate of radial growth is also greater than for other species associated with it (Figure 2). Height and diameter growth translate into a decided yield advantage for white pine on a given site (Table 1). On medium to poor sites, white pine produces basal area and volume yields that far surpass any other species except Virginia pine. On relatively poor sites, the fastest growing oaks produce less than one-half the cordwood volume and only about one-fifth the sawtimber volume of white pine. Even where site index rating for white pine is slightly less than that for yellow-poplar, white pine produces substantially more cordwood and sawtimber in a given time. On the basis of comparative yields, therefore, white pine certainly seems worthy of more attention.

In this paper I describe the growth and yield characteristics of both natural and planted stands, some of the factors affecting yield, and management to improve yield of useable products.

Plantation Growth and Yield

Most of the information on growth and yield of white pine in its southern range comes from plantations. The bulk of that data comes from a study by Vimmerstedt (1962). From a total of 78 plantations in North Carolina, Tennessee and Georgia, Vimmerstedt developed site index curves, individual tree volume tables, and equations for projecting cubic- and board-foot yields and mean stand diameter. Unless otherwise credited, statements that I make about plantation growth and yield are based on Vimmerstedt's findings.

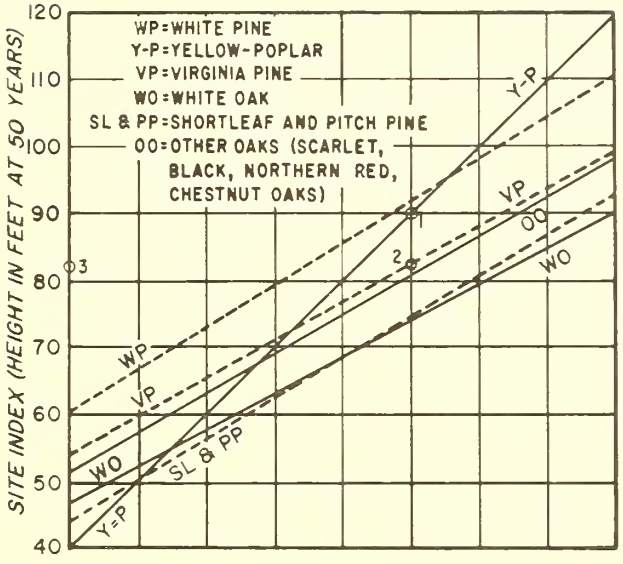

Figure 1--A comparison of site indices for 10 species on the same land in the Southern Appalachians. For example, on land that is site index 90 (1) for yellow-poplar, read down (2) and across (3) to find that this same land averages about site 82 for Virginia pine. Site index for white pine is about 92. (From Doolittle 1958)

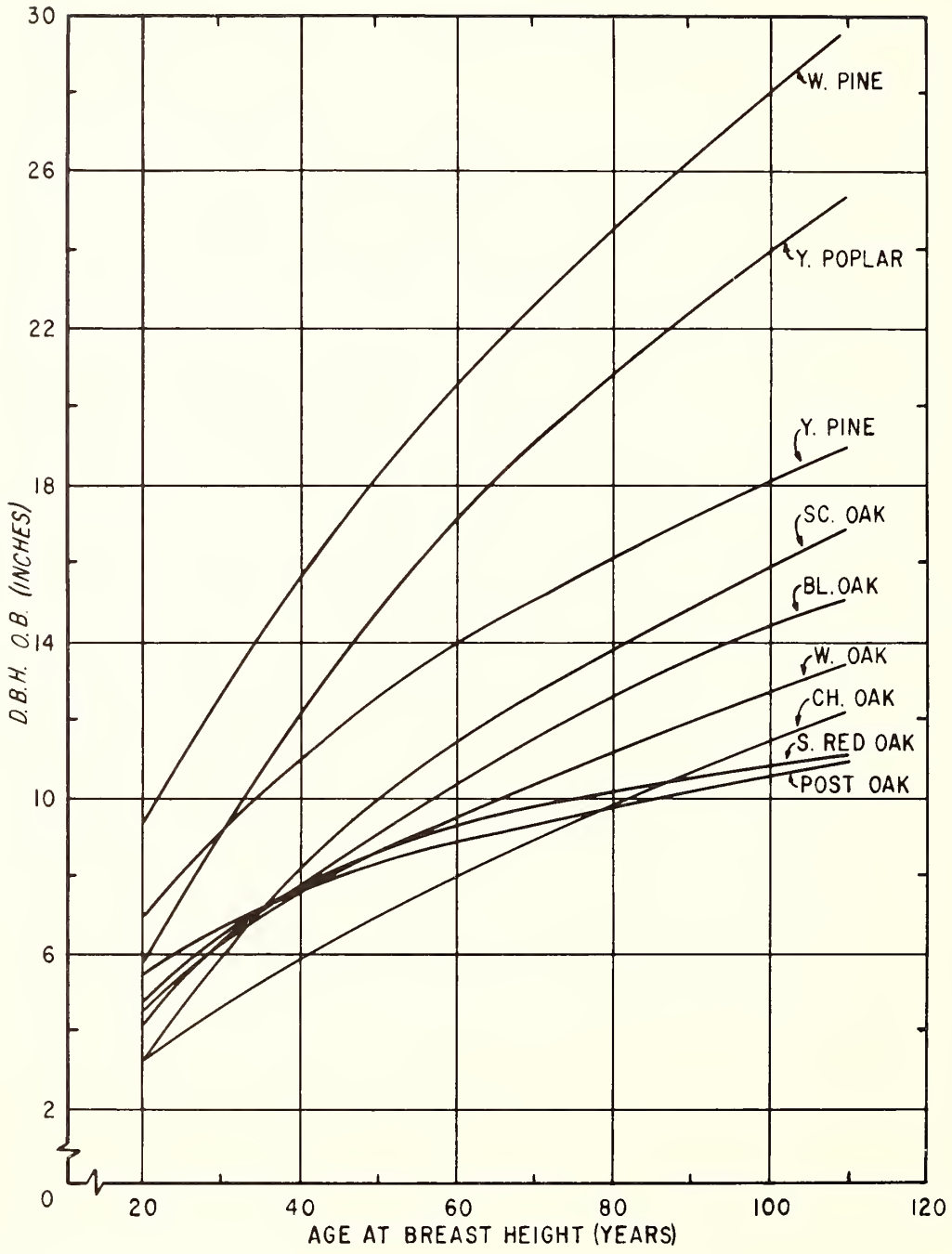

Figure 2--Comparative diameter growth of white pine and associated species. (From Barrett 1933)

Table 1--A comparison of site indices, basal area, and volume at 50 years for 10 Southern Appalachian species on 3 sites (From Doolittle 1958)

Species	Site Index	Basal Area per acre	Volume per acre*		
	Feet	Sq.ft.	Cu.ft.	Cords	Bd.ft.
		Poor Site			
Shortleaf and pitch pine	50	159	3970	46.7	9,900
Yellow-poplar	50	90	1700	20.0	3,500
White oak	52	90	1726	20.3	3,860
Other oaks+	57	94	2041	24.0	5,385
Virginia pine	59	162	4180	49.2	20,000
White pine	66	190	5312	62.5	23,920
		Medium Site			
Shortleaf and pitch pine	65	166	5665	66.6	22,750
White oak	66	100	2590	30.5	8,370
Other oaks	72	103	2954	34.8	10,550
Virginia pine	74	180	5440	64.0	28,840
Yellow-poplar	75	132	3138	36.9	14,510
White pine	82	201	6976	82.1	35,964
		Good Site			
White oak	79	106	3388	39.9	13,350
Shortleaf and pitch pine	81	170	7487	88.1	36,465
Other oaks	86	108	3870	45.5	16,300
Virginia pine	88	188	6040	71.1	39,116
White pine	98	205	8256	97.1	45,328
Yellow-poplar	100	172	5330	62.7	32,150

*Conversion factor for cordwood was 85 cubic feet per cord. Board-foot volumes are international 1/8-inch rule.

+Includes scarlet, black, northern red, and chestnut oaks.

Height Growth and Site Index

Height growth during the first 2-3 years of both planted and natural white pine is very slow. But afterwards, growth accelerates rapidly. Frothingham (1914) stated, "Thus 1, 2, and even 3 year old seedlings are so inconspicuous that they are likely to be overlooked, especially when among grass or weeds. During the following two seasons, when rapid growth commences, the top shoots of the seedlings appear everywhere, giving the impression that they have sprung up in a single year."

Once underway, height growth peaks somewhere between the 10th and 15th year. On the average site in Vimmerstedt's study (site index 56 at 25 year base age) height growth averaged 3.0 feet per year between the ages of 10 and 15 years. This slows to 2.2 feet per year for the first 25 years and to less than 1 foot between 25-50 years. Using the same time spans, height growth on the best sites (S.I=80) fell from an average 4.6 to 3.2 and 1.4 feet respectively. On all sites the rate of height growth at 50 years of age is about 1 foot per year. Apparently, growth is sustained at this level for a fairly long time, but the contribution of height growth to volume growth from 50 years on is very small.

Basal Area Growth

Basal area growth of white pine is also impressive. Rapid growth occurs during the first 20 years. Afterwards, basal growth slows similar to height growth patterns. In Figure 3, the curve labelled A shows basal area in relation to age for the average of all stands in Vimmerstedt's study, i.e., averaged overall planting densities and sites. On the average site nearly 160 square feet of basal area per acre has accumulated by 20 years of age--a mean annual increment (MAI) of nearly 8.0 feet per acre. After 30 years, the rate of increase begins to drop rapidly and is less than 1 square foot per acre per year between 50 and 60 years.

Plantations on some of the more productive sites accumulate 230-240 square feet per acre in 20 years--a MAI of nearly 12 square feet per acre per year over 20 years.

Curve B in Figure 3 is the basal area observed by repeated measurements in one plantation on the Biltmore Estate. It is shown as substantiation for the average curve derived from one-time measurement of many stands of different ages. Except for some anomalies at older ages, the correspondence between curves is very good.

Cubic-foot Yields

Vimmerstedt (1962) found that merchantable cubic-foot growth and yield of plantations was strongly influenced by site quality and to some extent by stand density expressed as original spacing.

Stand density.--The effect of planting density on cubic-foot yield is shown in Figure 4. As shown for the average site (Site 55) cubic-foot yield steadily increases with numbers of trees planted. The amount of the difference in yield between spacings depends on the age at which it is measured. The max-

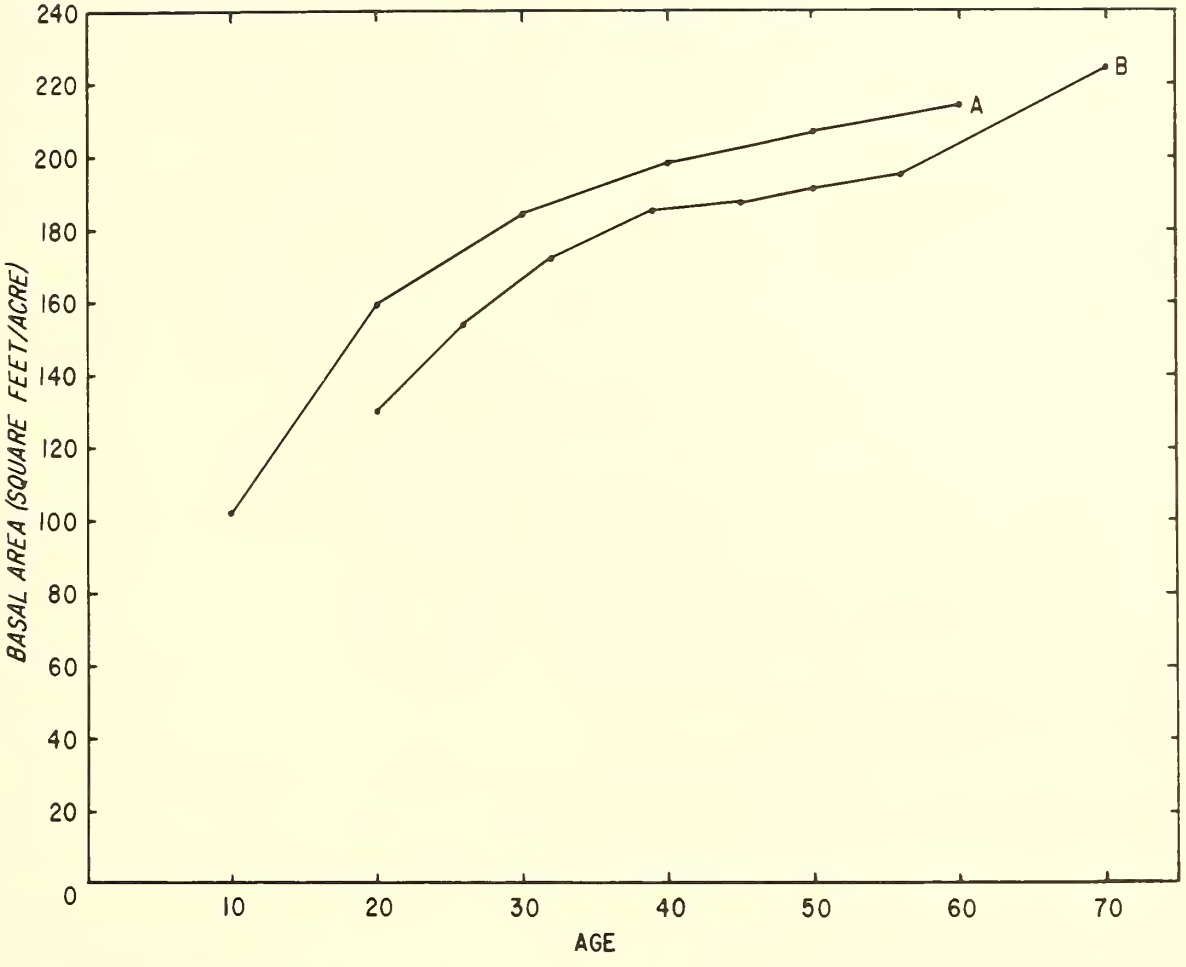

Figure 3--Stand basal area in relation to age for (A) average curve derived from one-time measurement of many stands of different ages (B) one plantation on Biltmore Estate derived from repeat measurements.

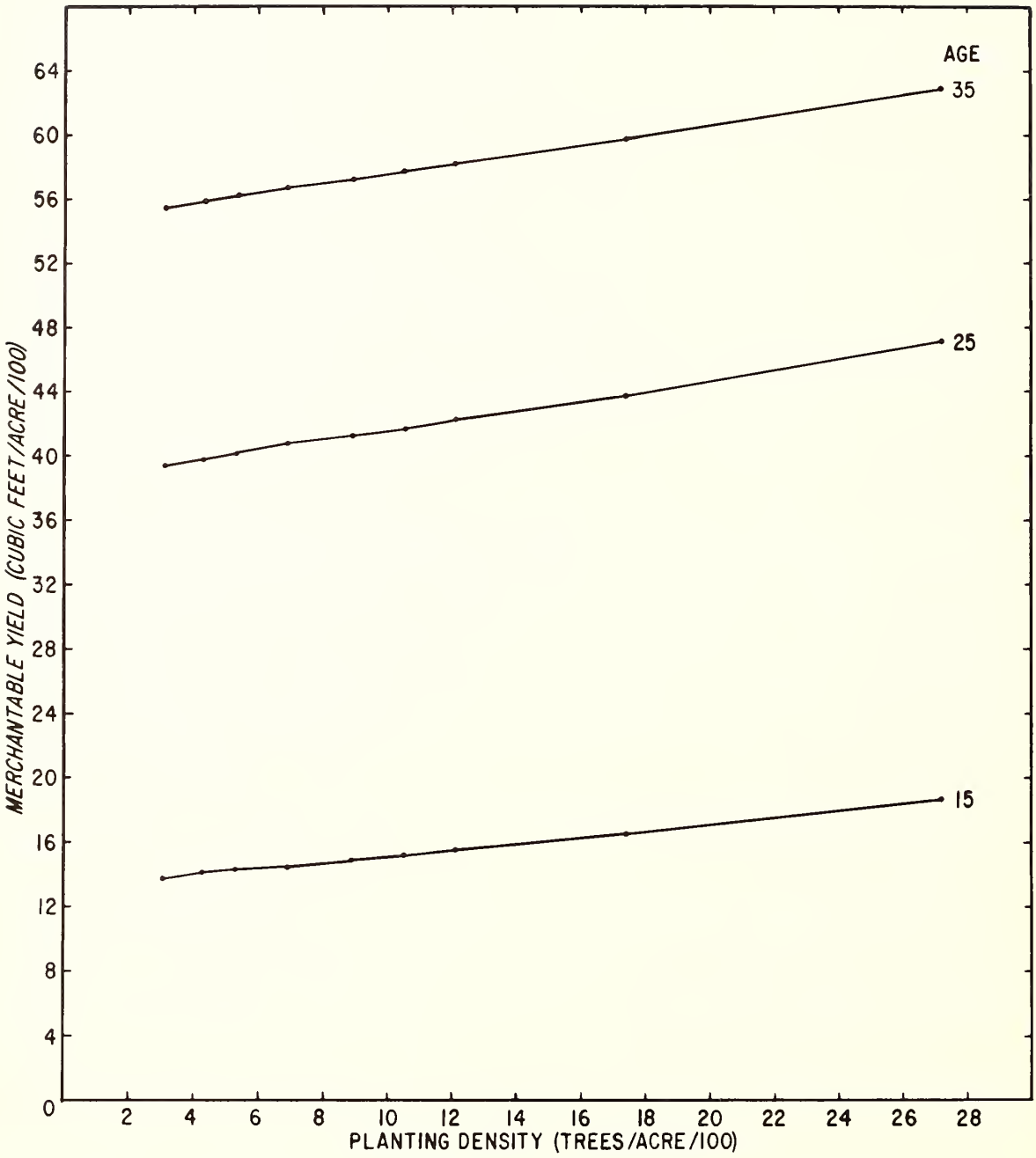

Figure 4--Cubic-foot yield per acre on Site Index 55 in relation to number of trees planted. (After Vimmerstedt 1962)

imum difference in stands planted at 4 by 4 foot spacing (2,722 trees/acre) and those planted at 12 by 12 foot (302 trees/acre) is about 9 cords (calculated at 85 cubic-feet/cord) at 30 years of age. Beyond 30 years of age there is a decrease in both absolute and relative yield between spacings. This is probably due to increasing mortality in the closely spaced stands with increasing age.

Site index.--The very strong effect of site quality on cubic-foot growth and yield is illustrated in Figure 5. In this figure mean annual increment (MAI) is shown in relation to age by site index classes. At culmination of MAI (approximately 25 years), the highest quality site (site index 75) produces a MAI of 387 cubic feet, whereas the lowest quality site (site index 45) produces MAI of only 118 cubic feet. Cordwood production is 4.6 per acre per year on site 75 and 1.4 on site 45. On the average site in Vimmerstedt's study, MAI at 25 years was 188 cubic feet or 2.2 cords.

Maximum periodic annual rate of cubic volume growth apparently occurs between 20 and 25 years of age and reaches nearly 3 cords per acre on the average site. On the very best sites, periodic annual increment (PAI) apparently reaches the almost unbelievable rate of 526 cubic feet or about 6 cords per acre at 4 by 4 spacing.

It must be remembered that the rates cited are based on one-time measurement of many stands of different ages rather than a series of measurements in single stands. They are, therefore, subject to error. However, well-documented independent observations support the data. For example, a plantation in Iowa planted at 7 by 8 foot spacing on a site that falls between site index 50 and 55 on Vimmerstedt's curves, contained about 82 cords per acre at age 51 (Brinkman and Krajicek 1950). MAI was 1.6 cords per acre. On a similar site with similar spacing, Vimmerstedt's tables would predict 60 cords at 35 years. Extrapolation to age 51, therefore, would produce yields close to those observed in Iowa.

In another case, Cope (1932) reported on a 22-year-old plantation near Highlands, North Carolina, in which the dominant trees were between 45 and 55 feet tall. It had grown at the rate of 240 cubic feet (2.8 cords) per acre per year, close to predicted yield on Vimmerstedt's tables.

Mean Stand Diameter and Board-foot Yield

Site quality, stand age, and planting density all strongly affect mean stand diameter (diameter of tree of average basal area) and board-foot growth and yield of plantations. Development of mean stand diameter on site 55 land is shown in Figure 6 for selected spacings. This figure shows a steadily increasing difference between mean diameter of the different planting density shown (300 trees/acre vs. 2700 trees/acre), the difference in mean diameter is 2.3 inches at 10 years and 4.1 inches at 35 years.

Board-foot yields are much greater also (Figure 7) as a consequence of larger average diameter in plantations with wider spacing. The trend of board-foot yield with number of trees planted is just the opposite of the trend of cubic-foot yield (compare Figure 4 and Figure 7). Board-foot yield sharply increases with increased space per tree at the widest spacings reported by

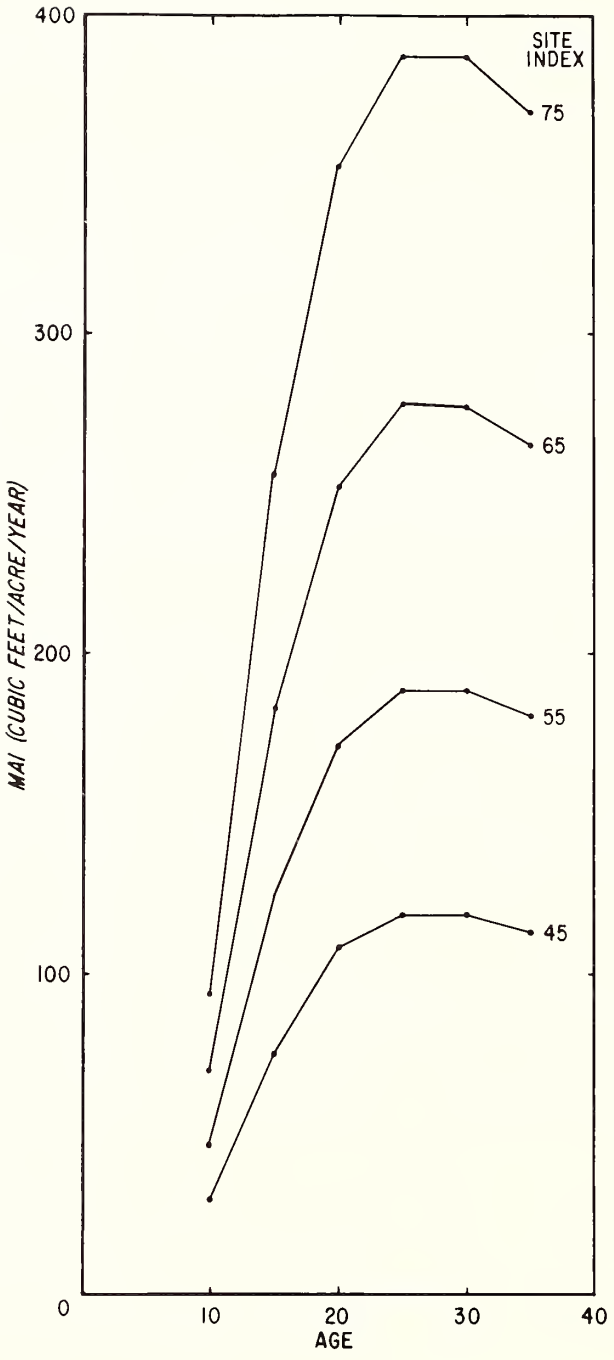

Figure 5--Mean annual increment in cubic-foot volume for white pine plantations by age and site index at 4 by 4 spacing. (After Vimmerstedt 1962)

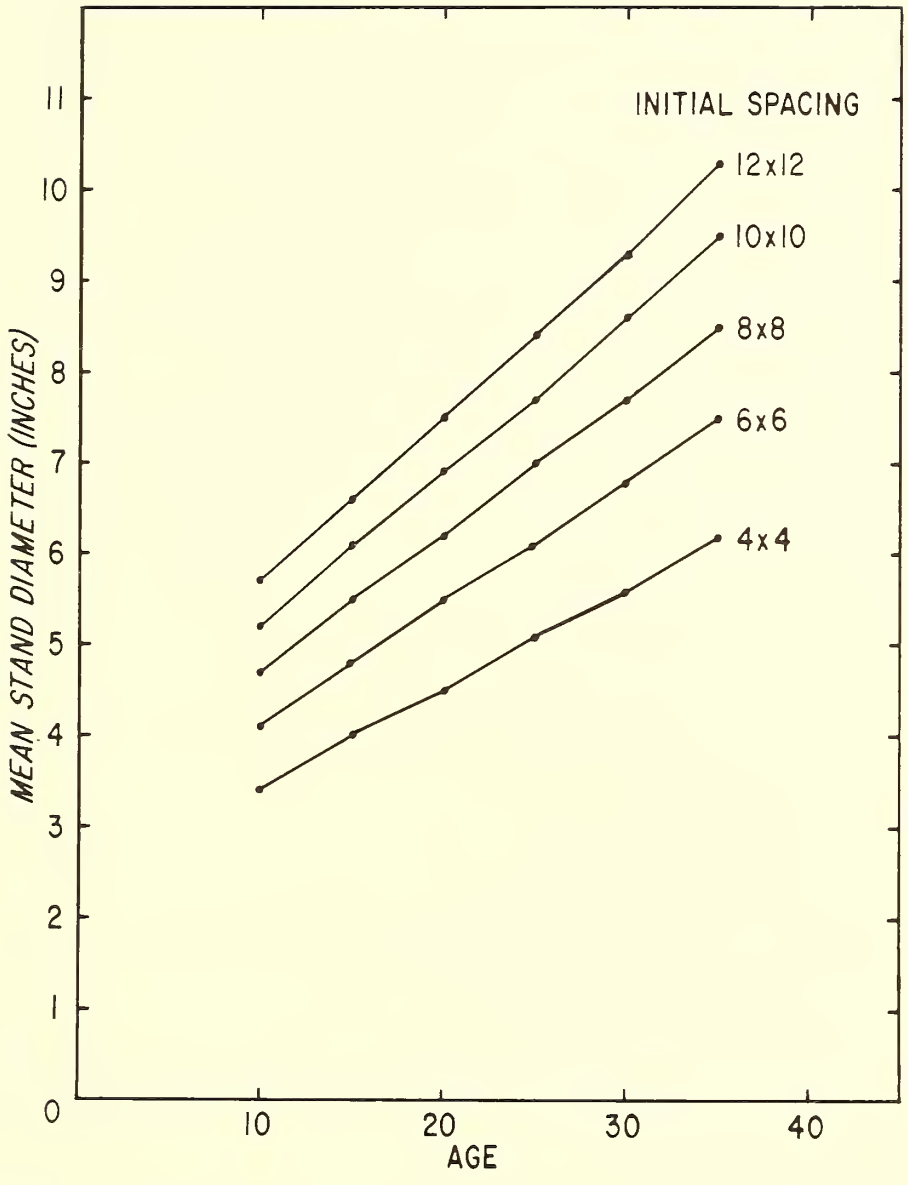

Figure 6--Mean stand diameter in relation to age for selected original spacings on site 55 land (After Vimmerstedt 1962)

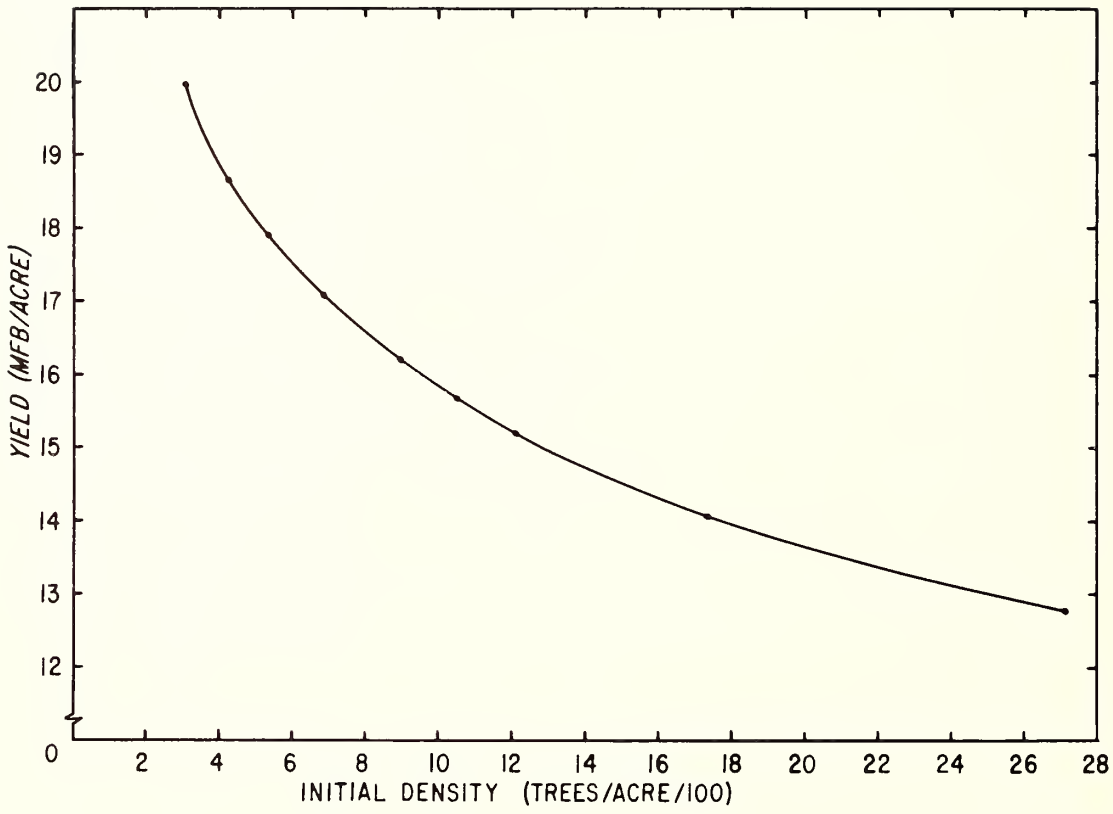

Figure 7--Board-foot yield (International ¼-inch rule) at 35 years of age on site 55 land for plantations established at various spacings. (After Vimmerstedt 1962)

Vimmerstedt. Presumably, a point would come where there would be too few trees to fully utilize the site and board-foot yield would decrease as spacing increased. In one plantation established at a very wide 16 by 16 foot spacing (170 trees/acre), board-foot volume at 36 years of age was only 28.8 mbf. per acre on site 70 land. Vimmerstedt's tables indicate a board-foot volume for a 12 by 12 spacing (302 trees/acre) under similar circumstances of site and age in excess of 43 mbf per acre. Basal area in the widely spaced stand was only 168 square feet per acre, much less than would be expected at closer spacings. These data indicate that somewhere between 12 by 12 and 16 by 16 foot spacing trees planted are not enough to fully utilize the site for board-foot production.

Based on the available data, culmination of MAI in board-foot volume appears to occur much later than MAI for cubic-foot volume. MAI for 12 by 12 spacing can be seen to be increasing at a fairly high level across all sites (Figure 8) at 35 years of age. Closer spacings show a similar trend. It can be seen in figure 9, however, that periodic annual increment (PAI) had already begun to decrease in the period from 25 to 30 years of age on the average site with 12 by 12 spacing. Based on the mathematical relationship between MAI and PAI, data from a few older plantations and knowledge of other species, it appears that MAI in board-foot volume will culminate somewhere around 50 years of age. The culmination probably will come somewhat sooner on the better sites than on poorer ones; perhaps as much as 5-10 years sooner. An indication of this phenomenon is that PAI can be shown from available data to peak earlier on the better sites than on the poorer ones for a given spacing. For example, at 12 by 12 spacing maximum PAI occurs on site 75 land between 20-25 years of age, whereas PAI on site 45 land occurs between 25 and 30 years of age. Earlier culmination of PAI and MAI on good sites is probably a result of more trees crossing the merchantable threshold sooner due to more rapid diameter growth.

Thinning Plantations

Up to this point, everything I have said about growth and yield pertains to unthinned plantations. What might we expect of thinned plantations? And what kind of thinning regime is best for given objectives?

The direct evidence on which to base answers is slim. Much of what we can say about thinning plantations is strictly circumstantial. One of the few published thinning experiments--and most well known--is that conducted in the plantations established at the Biltmore Estate, Asheville, North Carolina, by Dr. Carl Schenck (Della-Bianca 1970, Frothingham 1942, Wahlenberg 1955). The Old Orchard Plantation at Biltmore was established in March 1899 with 4-year-old seedlings spaced approximately 3 by 4 feet. In 1916, a thinning experiment was established in a portion of the plantation (Frothingham 1942). The study consists of a ¼-acre thinned plot and two 1/8-acre unthinned check plots. Thinning and measurements were repeated at approximately 6-year intervals up to 1952. After a lapse of 14 years, the plantation was thinned twice more. The thinnings were mostly very light with the smaller, poor vigor, poor risk trees being removed. In comparing "thinned" to the "unthinned" stand development on similar site quality, I followed the lead of Della-Bianca (1970) (Earlier reports by Wahlenberg (1955) combined the two unthinned plots--one of which had a much lower site index than the thinned plot--and drew somewhat different conclusions about the effect of thinning).

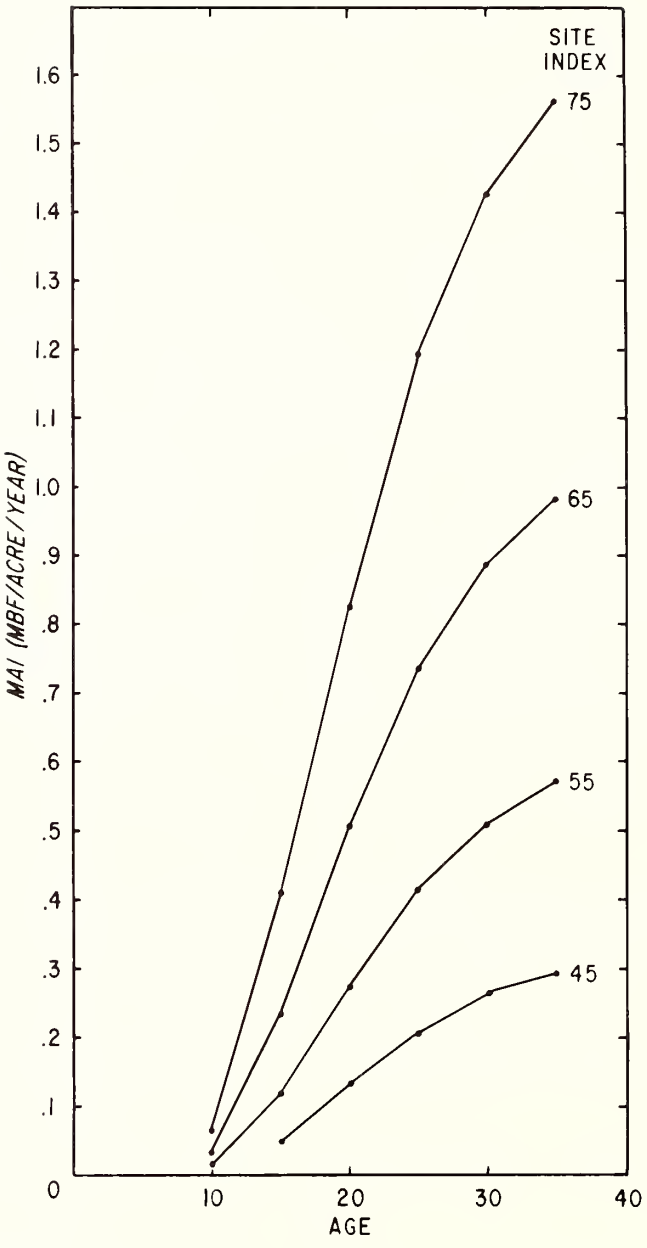

Figure 8--Mean annual increment in board-foot volume by age and site quality for stands planted at 12 by 12 spacing. (After Vimmerstedt 1962)

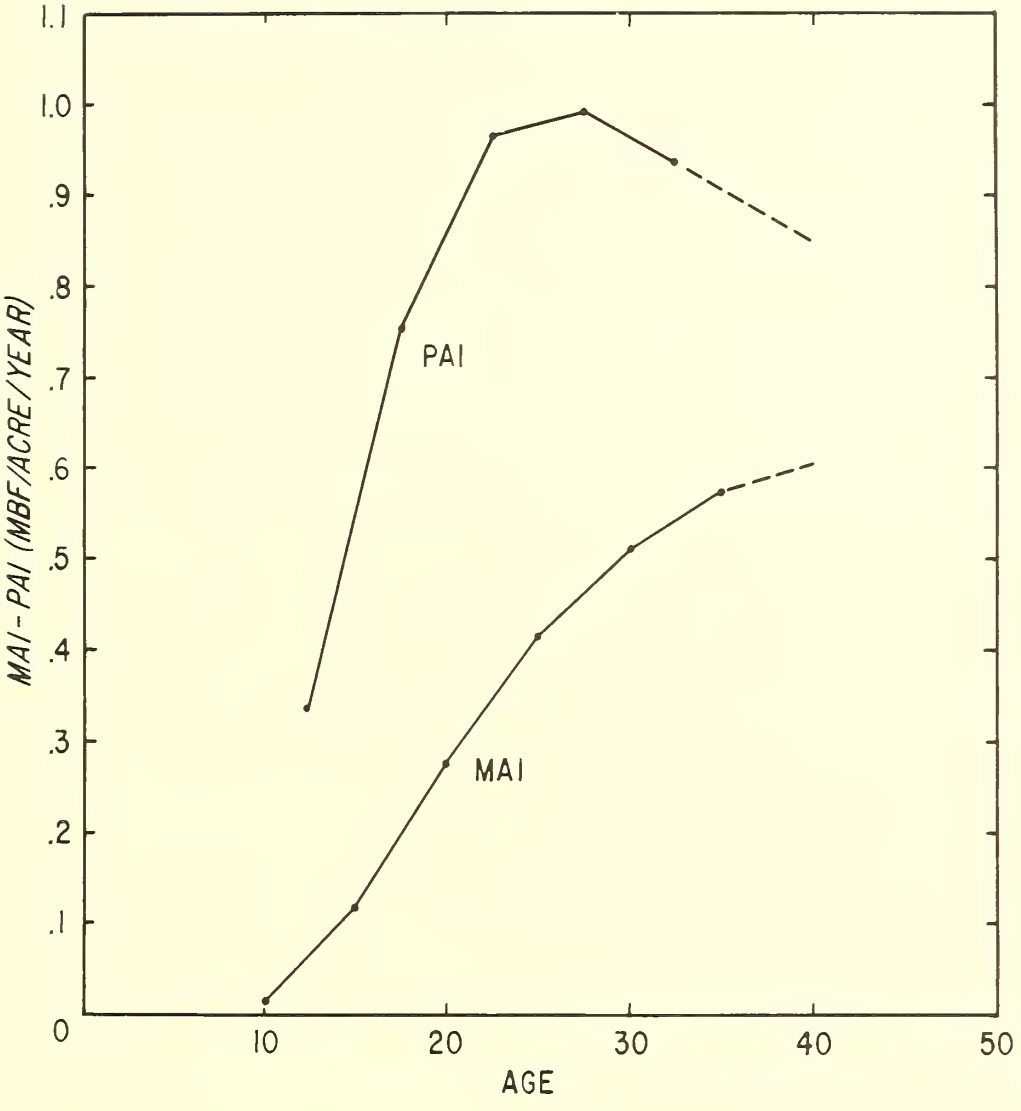

Figure 9--Mean annual and periodic annual board-foot increment for stands planted at 12 by 12 spacing on site 55 land.

A capsule history of the thinning experiment is shown in Table 2. If we adjust for the disparity in cubic-foot volume at the start of the study, we could conclude that the thinned stand has produced more useable cubic yield than the unthinned. Between the ages of 20 and 72, the thinned stand produced 11,092 cubic-feet (3,266 cubic-feet came out in thinnings). The unthinned stand produced a total of 9,886 cubic-feet during the same period. Most of the difference was due to salvage of trees ordinarily lost because of natural mortality. After the first thinning few, if any, trees died and were unsalvaged. In the unthinned stand, 792 trees per acre--over 3.5 inches d.b.h.--were lost between the ages of 20 and 72 years. But this loss had no adverse affect on board-foot volume. Over the first 72 years, the unthinned stand produced slightly more total yield (Note that very little board-foot volume was removed in thinning--less than four percent of the total produced. Most of the trees removed were simply too small to be merchantable for sawtimber. On the other hand, few trees of sawtimber size were lost through mortality in the unthinned stand). Although the average diameter of the thinned stand was larger than that of the unthinned stand at 72 years of age (14.4 inches vs. 12.0 inches), the 152 largest trees per acre in the unthinned stand had an average diameter of 14.3 inches--about the same as the largest trees in the thinned stand. The obvious conclusion is that light thinning did not accelerate diameter growth of the residual trees to any greater extent than natural mortality. Since there was little sawtimber taken out in the thinnings, the net effect of thinning was actually a reduction in board-foot yield. Somewhat similar results for very light thinnings were reported for a white pine plantation in Michigan (Spurr et. al. 1957).

In an Iowa plantation, different intensities of thinning were begun when the stand was 50 years old (Green and Pruett 1963). Three levels of thinning classified as light, medium and heavy, removed 18, 27, and 34 percent of the basal area respectively. However, even the heaviest thinning left a stand of 200 trees with 149 square feet of basal area per acre. The conclusion drawn 11 years after thinning was that none of the thinning levels restored the plantation to its former vigor and productivity. Growth differences in the thinned and unthinned plots were slight.

The few thinning studies published indicate that thinnings will have to be fairly heavy and begun at an early age if we wish to stimulate diameter growth of residuals and increase board-foot volume yield. This approach would be consistent with the relationship demonstrated between board-foot yield and initial spacing. That is, board-foot yield--at least in young stands--is appreciably greater in those stands grown at wide spacing from a very early age.

Management Strategy for Cubic-foot-yield

Two things are clear about cubic-foot volume growth of plantations. Mean annual increment in cubic-foot volume reaches a maximum around 25 years of age. And, cubic-foot yield at such young ages increases with the number of trees planted. Thus, if increased production of cubic-foot yield is a primary objective, the indicated management strategy would be to plant at very close spacing and harvest at around 25 years of age. The total yield, of course, would vary strongly with site quality, with the best sites giving three-fold the yield of the poorest. However, if planting costs and size of material produced are considered, it is doubtful if anyone would choose to plant at the very close spacings characteristic of many older plantations.

Table 2--Comparison of thinned (T) and unthinned (U) plots in the Old Orchard Plantation at Biltmore

Year	Age From Seed		# Trees T	# Trees U	$\bar{D}$ T	$\bar{D}$ U	Basal Area T	Basal Area U	Yield Ft. T	Yield Ft. U	Yield M.B.F. T	Yield M.B.F. U
		Before	888	1,088	4.6	4.7	99	130	1,790	3,218	--	--
1916	20	Cut	144		4.2		14		247		--	
		After	744		4.6		85					
		Before	828	984	5.2	5.4	123	154	2,309	4,067	--	--
1922	26	Cut	352		4.5		39		694		--	--
		After	476		5.7		84		1,615		--	
		Before	480	848	6.7	6.1	113	172	2,623	4,922	1.5	.6
1928	32	Cut	116		5.4		18		365		.3	
		After	364		6.9		95		2,258		1.2	
		Before	368	704	7.8	6.9	121	185	3,042	5,597	5.0	6.1
1935	39	Cut	56		6.4		12		280		--	
		After	312		8.0		109		2,762		5.0	
		Before	312	560	9.0	7.8	134	187	3,335	6,070	9.3	10.1
1941	45	Cut	100		7.7		32		816		.7	
		After	212		9.4		102		2,519		8.6	
		Before	212	496	10.1	8.4	118	191	3,361	6,442	12.6	13.9
1946	50	Cut	-		-		-		-		--	
		After	212		10.1		118		3,361		12.6	
		Before	212	400	11.0	9.5	139	195	4,176	8,458	17.8	20.3
1952	56	Cut	60		8.7		24		864		.8	
		After	152		11.8		115		3,312		17.0	
		Before	152	296	14.4	12.0	173	232	9,616	13,104	44.1	51.6
1967	72	Cut										
		After										
Total Product									12,882	13,104	45.9	51.6

Management Strategies for Board-foot Yield

If the management goal is to produce maximum board-foot yield in reasonably short rotations (say 35-40 years) without thinning, plantations should be established at wide spacings. A spacing of about 12 by 12 feet (302 trees/acre) appears to be a reasonable goal. Published tables show that at closer spacing board-foot yield per acre on short rotations decreases. And there are pretty good indications that spacings wider than 12 by 12 will produce less board-foot volume. There are some indications that imposing a fairly heavy thinning at an intermediate age with a slight lengthening of the rotation might be a viable alternative to no thinning. But there is simply not enough information available at this point to make firm recommendations about thinning plantations.

Natural Stands

Growth and yield information for natural white pine stands in the southern range is scarce. However, the species does seem to exhibit the same remarkable growth traits in natural stands as it does in plantations.

Height growth and site index information for natural stands in the Southern Appalachians was developed by stem-analysis techniques (Beck 1971). This work suggests that natural stands may grow at relatively slower rates during the early years than the old-field plantations studied by Vimmerstedt. One explanation might be greater competition from overtopping trees and other vegetation in the natural stands in comparison to old-field plantations. Even so, natural stands do exhibit fast rates of height growth with internode lengths of 3 feet not uncommon.

The published yield information being used for natural stands in the Southern Appalachians was adapted by Doolittle from Wisconsin data (Marty 1965). The reliability of the information is unknown. For what it's worth, it shows that natural stands apparently exhibit slightly different growth and yield characteristics than plantations. Basically, rates of growth in basal area, cubic-foot and board-foot volume appear to be somewhat slower in the early stages of development. For example, maximum MAI in cubic-foot volume doesn't occur until 60-70 years as opposed to 25 years in plantations. MAI in board-foot volume is shown to be increasing at 100 years, albeit slowly.

Information on thinning natural stands is scarce. However, the fact that high levels of basal area accumulate rapidly suggests that early thinnings would be necessary to boost diameter growth of individual trees and increase board-foot yields. For example, on a moderately good site (Site Index 80 at base age of 50 years) the average stand has accumulated 155 square of basal area at 30 years. Experience with other species such as the southern pines and yellow-poplar show that board-foot growth rates can be maintained at nearly the maximum possible with residual basal areas that are half that level. Also, rates of diameter growth of individuals are markedly increased by thinning to lower levels of basal area.

Summary

Growth and yield information for white pine in the South is far from plentiful. However, there is enough evidence to show that the species can achieve

remarkable rates of growth and produce cubic-foot and board-foot volumes far in excess of other species across a wide range of sites. It seems certain, also, that with a modest degree of stocking control through regulation of planting space or early thinning, the species can be managed to produce considerable sawtimber volumes on relatively short rotations.

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TREE IMPROVEMENT: VIRGINIA AND WHITE PINE

by

Eyvind Thor [1)]

ABSTRACT. Large, open-pollinated heritability tests have been used to determine the variation in Virginia and eastern white pine. Variation in height growth among seed sources of white pine from the Southern Appalachians is large, but much variation among families from the same source is also present. Variation in volume growth among seed sources of Virginia pine from Kentucky and Tennessee was slightly less than the among-family variation. Heritability estimates for height in white pine ranged from 0.31 to 0.37 and for stem volume in Virginia pine from 0.15 to 0.22. Combined family and within-family selection resulted in genetic gains of about 20 percent in both species.

Breeding programs with both Virginia pine (Pinus virginiana Mill.) and eastern white pine (Pinus strobus L.) have been active at The University of Tennessee for 15 years. Results obtained through 1975 have been reported (Thor, 1976); more recent data are presented in this paper.

VIRGINIA PINE

Although considered an inferior species by some foresters due to its persistent branching habit there is now considerable interest in the improvement of Virginia pine. This interest is due to the good volume and dry weight yield on relatively poor sites and the suitability of the wood for certain paper products. The ability of the species to become established on poor sites has made it desirable in strip mine reclamation. Even on very acid spoils (pH less than 4.0) Virginia pine plantations may be established (Thor, et al., 1974).

Available information on the variation in Virginia pine was compiled by Kellison and Zobel (1974). They concluded that the large variation existing among trees could be utilized in a tree improvement program.

Materials and Methods. In 1962 the Kentucky-Tennessee Section of the Society of American Foresters decided to support a study to determine the variation in natural populations and in open-pollinated progenies from mother trees selected in these populations. A large proportion of the total variation in the natural populations was accounted for by the among-tree variance component (Thor, 1964).

Seed was collected from at least 10 sample trees in 12 stands and 1-year-old progenies were outplanted in four locations in Tennessee: West Tennessee, Highland Rim, Cumberland Plateau, and the Great Valley. In addition plantations were established in North Alabama and on a reclaimed strip-mine in East Kentucky. Approximately 60,000 trees were planted, representing 128 of the trees samples for the study of natural variation.

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Plantations were evaluated after two, five and eight years in the field (Evans and Thor, 1971; Rink and Thor, 1976; Meier and Goggans, 1977). Reported here are data for volume growth following 10 growing seasons in three plantations (Cumberland Plateau, Highland Rim, and West Tennessee). Statistical analyses were based on single tree observations to obtain the variance components needed to determine heritability and to estimate expected gains from a selection breeding program.

Results. To determine if seed source selection is of importance in Virginia pine the average volume per tree for stands (seed sources) was computed. Table 1 presents both the average tree volume for each stand and its ranking among the 12 stands. In each plantation there are considerable differences among seed sources; in general, trees from the poorest source grew about 70 percent as much as those from the best source. Seed sources which ranked high at one location also performed well at the other two locations; similarly, trees from poor sources are consistent in their inferior performance. Two east Tennessee sources (Etowah and Vonore) ranked high in all three plantations while the Dawson Springs, Kentucky source ranked last at all locations.

Combining the data from all three locations confirms these conclusions (Table 2). The Duncan Multiple Range test separated superior from intermediate and inferior seed sources for volume growth.

Variance components are expressed in Table 3 as percent of total variance (100%). Most of the variation in volume growth occurred within the 10-tree family row plots. Since progenies within families are half-sibs much genetic variation must be expected at this level in addition to the environmental effects present within the row-plots. Most of the remaining variation was accounted for by the among-family and among-stand genetic variation. Genotype x environment interaction effects were small.

Heritability for volume growth was computed for each location by using the standard formula for half-sib families. Resulting estimates varied from a low of 0.15 on the Cumberland Plateau to a high of 0.22 for West Tennessee.

It was decided to convert the Cumberland and West Tennessee plantations to seedling seed orchards. The best 27 families out of the 90 present in each plantation were selected; all progenies belonging to the remaining 63 families are gradually being removed. In addition to this family selection, individual selection was carried out within each family row-plot; only the best progeny within each row-plot was retained. The expected genetic gains following this roguing are presented in Table 3. Expected gains in volume growth of 17 percent for the Cumberland Plateau plantation and 28 percent for the West Tennessee plantation compares very favorably with most first-generation selection results for other Southern pines. Roguing has already been initiated in the two plantations. It is expected that with proper fertilization and maintenance these two seed orchards, containing a total of 540 trees, will provide sufficient seed to satisfy the anticipated demand of 2 to 4 million seedlings per year for the state of Tennessee.

Table 1. Volume of Virginia pines from 12 stands after ten growing seasons in three locations.

Stand Origin	Cumberland Plateau		Highland Rim		West Tennessee	
	Volume, cuft.	Rank	Volume, cuft.	Rank	Volume, cuft.	Rank
Clifton, TN	--	--	.99	2	.59	3
Dawson Spr., KY	.77	10	.78	12	.44	11
Sewanee, TN	.88	9	.81	9	.51	9
Rock Island, TN	.92	7	.92	5	.55	5
Wartburg, TN	.95	5	.84	8	.52	8
Pineville, KY	1.03	2	.87	7	.57	4
London, KY	.93	6	.80	10	.49	10
Morehead, KY	.97	4	.79	11	.52	7
Etowah, TN	1.09	1	1.06	1	.70	1
Vonore, TN	1.02	3	.95	3	.61	2
Newport, TN	--	--	.93	4	--	--
Elizabethton, TN	.91	8	.89	6	.53	6
Mean	.95		.89		.55	

Table 2. Volume of Virginia pines from 12 stands after 10 growing seasons combined for three locations.

Stand No.	Stand Origin	Volume, cuft.[1)]
10	Etowah, TN	.95
12	Newport, TN	.93
1	Clifton, TN	.89
11	Vonore, TN	.85
7	Pineville, KY	.81
4	Rock Island, TN	.80
13	Elizabethton, TN	.79
6	Wartburg, TN	.77
9	Morehead, KY	.76
3	Sewanee, TN	.74
8	London, KY	.73
2	Dawson Spr., KY	.67

1) Stand values connected with the same line are not significantly (5% level) different.

Table 3. Variance components, heritabilities and estimates of gain in stem volume (percent) for Virginia pine in three locations.

	Percent		
	Cumberland Plateau	Highland Rim	West Tennessee
Within plot variance	91	91	88
Among family variance	4	5	5
Repl. X family variance	2	0	2
Among stand variance	3	3	5
Repl. X stand variance	0	1	0
Heritability	15	20	22
Gain family selection	10	--	17
Gain within family-selection	7	--	11
Total gain from selection	17	--	28

WHITE PINE

Until about 20 years ago the demand for white pine seedlings was small. Inadequate forest fire control was one reason; since white pine is very susceptible to killing from even a low intensity fire it was not favored in regeneration programs. Greatly improved fire control has made it possible to establish white pine plantations for timber production. In addition, the use of this species for Christmas trees has greatly increased the demand for white pine seedlings.

Considerable information is now available on variation in eastern white pine; some of this was summarized by Wright (1970). However, most information on geographic variation and inheritance of various characteristics has only been obtained during the last few years.

Seed source tests established 20 years ago in Tennessee confirmed suspicions that the northern seed sources often used in Tennessee were inferior to seed sources from the Southern Appalachians. To better estimate variation of white pine in the Southern Appalachians, a plantation containing progeny from 26 stands was established on the Highland Rim near Tullahoma, Tennessee. Seed collections were made from the southernmost part of the species range in Georgia (Latitude $34^{\circ}43'$ N) to West Virginia (Lat. $39^{\circ}30'$ N). After five growing seasons in the field, trees from the three best sources were significantly taller (4.81 feet) than those from the eleven poorest (3.07 feet). All but one of the 11 poor sources came from Virginia or West Virginia. A regression analysis indicated

Table 4. Total Height of white pines from 13 stands after eight growing seasons in two locations.

Stand No.	County	State	Cumberland Mt.		Highland Rim	
			Height, ft.	Rank	Height, ft.	Rank
1	Monroe	TN	13.8	8	14.9	7
2	Polk	TN	16.3	4	15.9	4
3	Fannin	GA	13.8	7	15.3	5
4	Cherokee	NC	10.7	12	12.7	11
5	Madison	NC	11.6	11	14.5	9
6	Cocke	TN	12.8	10	14.0	10
7	Unicoi	TN	14.8	6	14.5	8
8	Unicoi	TN	14.9	5	15.0	6
9	Transylvania	NC	8.9	13	11.8	13
10	Carter	TN	13.0	9	11.9	12
11	Morgan	TN	16.8	3	16.2	3
12	Morgan	TN	17.3	1	16.6	2
13	Anderson	TN	17.2	2	17.1	1
Mean			14.4		14.8	

Table 5. Total Height of white pines from 13 stands after eight growing seasons combined for two plantations.

Stand location		Height, feet[1)]
County	State	
Anderson	TN	17.1
Morgan	TN	16.9
Morgan	TN	16.4
Polk	TN	16.1
Unicoi	TN	14.9
Fannin	GA	14.7
Unicoi	TN	14.6
Monroe	TN	14.4
Cocke	TN	13.5
Madison	NC	12.8
Carter	TN	12.2
Cherokee	NC	11.8
Transylvania	NC	10.7

1) Stand values connected with the same line are not significantly (5% level) different.

that 45 percent of all seed source variation in height was accounted for by latitude (Thor, 1974). The wide variation in height growth of trees from different stands at the extreme southern end of the species range suggested that more intensive sampling from this region would be necessary to capitalize on the apparent ecotypic variation.

Materials and Methods. Seed was collected from 10 sample trees in 13 stands and 2-years-old progenies were outplanted in four locations in Tennessee. Five years after planting, these tests were evaluated for height growth and resistance to air pollution damage (Gall and Thor, 1977; Thor and Gall, 1978). Reported here are data for height growth following eight growing seasons in the field. Only two of the four plantations (Cumberland Mt. and Highland Rim) were inventoried. Statistical analyses were based on single tree measurements making it possible to estimate heritabilities and genetic gains expected from a selection breeding program.

Results. Table 4 suggests that there is great variation among sources (stands) within the Southern Appalachian Region. In the two test plantations trees from the three stands in the Cumberland Mountains and adjoining Valley were consistently superior. Just as consistently, the three North Carolina sources ranked at the bottom. When data from the two plantations are combined (Table 5) performance of the different sources can be separated using Duncan's Multiple Range Test. Trees from the low elevation Morgan County and the Great Valley (Anderson Co.) sources are superior in height growth. These trees grew 59 percent faster than those from the poorest source (Transylvania, NC) and 17 percent faster than the average of the whole population representing the Southern Appalachian Region.

This variation among seed sources is reflected in a large among-stand variance component (Table 6). Since variance components are expressed as percent of total variation the variation within the 10-tree family row-plot is relatively modest (64 percent). In spite of the large stand component the among family (within stand) component is substantial, indicating that both stand and within stand selection will result in important genetic gains.

Table 6. Variance components, heritabilities, and estimates of gain in total height (percent) for white pine in two locations.

	Highland Rim	Cumberland Mountains
	Percent	
Within plot variance	64	64
Among family variance	7	6
Replic. x fam. variance	8	8
Among stand variance	21	22
Replic. x stand variance	0	0
Heritability	37	31
Gain family selection	10	16
Gain within fam. selection	8	10
Total gain from selection	18	26

Narrow-sense heritability for height growth was estimated to be .37 on the Highland Rim and .31 in the Cumberland Mountains. Although there are no immediate plans to convert the white pine heritability test plantations into seed orchards the expected genetic gain in juvenile height growth was computed. Selection of the best 30% of all families and selection of the best progeny within family rows resulted in gains of 18 percent in the Highland Rim plantation and 26 percent in the Cumberland Mountain plantation.

DISCUSSIONS AND CONCLUSIONS

Virginia pine. Poor performance of progenies from Kentucky in Tennessee tests indicates that northern sources of Virginia pine should not be used in Tennessee. This conclusion raises a question about the potential of seed from more southern sources. Since no sources from states south of Tennessee were included in these tests, no conclusive answer can be given. However, poor performance of trees from the southernmost source (Sewanee, near the Alabama border) does not indicate that gains in growth rate will be obtained by using more southern seed sources. Superior growth rate of trees from the central part of the East Tennessee Valley (Etowah, Vonore, Newport) indicates that this area should be used for collection of wild seed and selection of superior trees for future breeding work in Tennessee.

Substantial gains in growth rate are expected from converting the two Virginia pine test plantations to seedling seed orchards. Selection of orchard trees has been completed, but roguing of the remaining trees must be carried out gradually to prevent damage to the selected trees. For the next 5 to 7 years contamination of pollen from less desirable trees will result in gains substantially less than those calculated. After that time, however, gains in growth rate will be as good as or better than that obtained in grafted orchards of other southern pines.

Another reason for an over estimate of genetic gain is that the heritability was determined for individual plantations. If there is significant location x family interaction both heritability and gains will be reduced. However, the Virginia pine plantations were analyzed by combined analyses after 5 growing seasons and the interaction variance component accounted for less than one percent of the total variation and can thus be disregarded (Rink and Thor, 1976). This small interaction indicates that seed from both orchards may be utilized for plantations in all parts of Tennessee.

White pine. Three white pine stands from the extreme western part of the Valley (Anderson County) and the Cumberland Mountains (Morgan County) produced progenies with superior height growth. These three sources are separated from the 10 Blue Ridge sources by the Great Valley. Since there are very few native white pines in the Great Valley physiographic region the distance (about 30 miles) between the two groups may have been an effective barrier to transfer of genetic material (seed and pollen). Adaptation to specific growing conditions in the two different physiographic regions has probably taken place resulting in two different populations of white pine.

Since no test plantation was established in the Blue Ridge physiographic region it is not possible to make any conclusions regarding the relative growth

rates of seed sources in that region. However, the sources from Morgan and Anderson counties have produced superior progenies in four physiographic regions of Tennessee. Seed is now collected in Morgan County by the Tennessee State Division of Forestry for use in their nursery. This practice should continue until sufficient seed becomes available from seed orchards.

The white pine plantations are much too young for conversion to seedling seed orchards. Unlike Virginia pine, eastern white pine is not precocious. Although female flowers may appear after 10 years of age, little pollen production will occur before the trees are 20 years old. At that age progenies should be nearly half way through a sawtimber rotation and meaningful estimates of heritability and gains for volume growth and other important characteristics may be obtained.

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VIRGINIA PINE REGENERATION

by

John Kundt[1/]

NATURAL REGENERATION

Virginia pine (Pinus virginiana) is a prolific seed producer, having seed crops every year with above average seed crops occurring at 1-4 year intervals. A bushel of Virginia pine cones averages 2,244 cones (Slocum and Miller) and a pound of cleaned seeds averages 55,400 seeds with a range of 45,000 to 91,000 seeds (Krugman and Jenkinson). It is not uncommon to see cones on 5 year old trees, however, large volumes of seeds are usually obtained by trees over 30 years in age. In dense stands only the dominant and co-dominant trees produce cones. Studies on Virginia pine in Southern Maryland over a five year period indicated a range in seedfall from 48,000 to 996,000 seeds per acre (Fenton and Bond). Seed viability ranges from 2 percent in poor seed years to 80 percent in good seed years. Applying the percentage to the very poorest seed year with 6,400 seeds per acre, we only obtain 128 viable seeds/acre. In a bumper seed crops of 40,000 seeds/acre we obtain 32,000 viable seeds.

Some form of clear cutting is preferable to obtain natural regeneration because this species is intolerant and has a shallow root system. Seed bed preparation should expose the mineral soil and control the hardwood species to give the new seedlings freedom to grow. Research on natural regeneration of Virginia pine in Southern Maryland was begun in the early 60's with the strip clear cutting system. Cut strips 2 and 3 chains wide and leave strips one chain wide were laid out perpendicular to the prevailing winds. The cut strips were burned after the logging slash cured to form a seed bed and to control the hardwoods. Most cut strips were over-stocked with Virginia pine seedlings.

The 3 chain-wide cut strips received seedfall ranging from 6,400 to 40,000 seeds per acre the first four years after cutting. The 2 chain-wide cut strips received seedfall ranging from 8,200 to 54,900 seeds per acre during the same period. Some cut strips showed severe hardwood competition. Apparently the controlled burning did not burn hot enough to reduce the hardwood growth, (Fenton and Bond).

The one chain-wide leave strips were cut in the early '70's. No burning was done since the cut was made in the winter of an average seed year. Some strips had no pine reproduction three years after cutting and these strips were converted to game food plots. While other strips were fairly well stocked with Virginia pine seedlings with some hardwood encroachment.

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It has been suggested that the leave strips be treated with a light fire prior to cutting to stimulate advanced reproduction and control small hardwoods. This was tried experimentally and 54 percent of the seed trees were killed by the fire. However, advanced reproduction was established and after the final removal cut there was satisfactory stocking of pine seedlings. The economics and the timing of the fire may prove this method unacceptable.

Two other experimental methods have been tried in establishing adequate natural reproduction, 20 seed trees per/acre, and leaving small groups of seed trees. When adequate site preparation is done, one obtains satisfactory regeneration. However, blow-down loss is ever present.

If the timberland owner can wait for a bumper crop of seeds, he might clear cut after seedfall and let the logging activity accomplish scarification. A selective herbicide can be used to control undesirable hardwoods if the Virginia pine seedlings become suppressed.

PLANTING

Seedling regeneration has been very successful with bare root planting of Virginia pine, provided the planting site is adequate. Virginia pine can tolerate a wide variety of soils, however, optimal growth occurs on clay, loam, and sandy loam soils that are well drained. In my experience deep sandy soils along river courses can support good stands of Virginia pine. I have seen pole size trees with a 6-8 foot long taproots in deep sand soil along the Nanticoke River in Maryland, and trees in these stands were wind firm.

Planting sites should be prepared for Virginia pine as for loblolly pine. Bare root stock can be planted by hand or by machine with excellent results. In Maryland we obtain 80 to 90 percent survival with our planted seedlings the first year.

A few states still collect seeds from "wild trees" to grow in their nurseries, however, genetically improved seed is being used by most of the southern states. I would highly recommend reproducing Virginia pine by planting genetically improved stock. Where improved seedlings are available I would discourage natural regeneration in preference to trees that will grow taller, be better pruned, straighter and more vigorous than natural seedlings. Thus I would convert natural stands of Virginia pine to genetically improved stands. This could be accomplished with late spring clear cuts, summer burning and mechanical site preparation.

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VIRGINIA PINE MANAGEMENT

by
Dr. Kenneth L. Carvell[1/]

IMPORTANCE OF STOCKING AND SPACING

The success of every Virginia pine rotation depends primarily on obtaining a suitable number of pine seedlings--not too open and not too dense--all established at about the same time. The benefits from suitable stocking strongly emphasize the value of planting, and are felt throughout the rotation.

Stands that are too open give pines that are so limby that they are difficult to fell and costly to limb, plus a reduction in the site's growth potential during the early years of the rotation. Stands that are too dense may require pre-commercial thinning. If such thinnings are not used, the dense stocking results in slow growth hence longer rotations, unusable wood fiber deposited on many stems that can never reach pulpwood size, needless loss of carbohydrates from excessive respiration, and the possibility of stagnation.

Where stands have seeded-in gradually over several years, an additional problem is created in that those trees that became established first develop into coarse, spreading dominant trees. These take up needless amounts of growing space and crowd smaller trees.

I have experimented with spacing adjustments in dense, small-sapling-stage natural Virginia pine stands in the Ohio River area of West Virginia using a cleaning at age 6 to reduce the spacing to 6 by 6 feet, 7 by 7 feet, 8 by 8 feet, and 8.5 by 8.5 foot spacing. Ten years after these spacing adjustments, the widest spacing (8.5 feet) appeared the most promising, with the largest average diameter, greatest height, sturdiest boles, and a good breakdown into crown classes resulting in an orderly process of natural thinning (Carvell 1966).

In my experience the most densely-stocked Virginia pine stands in West Virginia have all seeded-in on open soil, garden areas that were plowed but not planted. If an abundant seed source is nearby, as many as 100,000 Virginia pine seedlings can become established per acre during the first year. Adjusting stocking and spacing in such stands is essential, and although the method of reducing stocking can vary greatly, this operation classifies as a cleaning.

The stocking of old-field stands which have seeded-in on grass sod varies with the fertility of the site, and reflects the density of the grass sod. On sites of average and fair quality, where the sod is thin, often a suitable number of well-distributed Virginia pine seedlings occurs per acre. However, these stands often exhibit the problem that most natural stands have, stocking is uneven--too dense near the seed source and too sparse 500 feet or more from the seed source.

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On fertile old fields, where grass sod is dense, and where grass reaches a height of 2 to 3 feet by late June, pine invasion is slow, resulting in uneven stocking, and a complexing variation in ages exists, since only a few pine seedlings successfully work their way through such competition each year.

In adjusting the spacing of dense natural stands of Virginia pine, various techniques can be used. Stands in the young sapling stage have been successfully treated by bulldozing parallel strips at regular intervals. Such strips are 6 to 8 feet wide, and are spaced at 8-foot intervals. These strips allow edge trees to develop into more sturdy individuals, and increase the rate of natural thinning within the remaining strips.

I do not feel that pelleted herbicides offer great promise in breaking stagnation in such stands, since picloram moves down slope readily for four or five years after application, and often kills many trees needed in the future stand. Hand cleaning is too slow and costly, but a cut-off brush saw may be practical.

A problem unique to understocked Virginia pine stands is that the hardwood understory invades more quickly. Two stands of the same age and appearance at age 20 may vary greatly in the extent of hardwood understory invasion. If these sites are similar in productivity, this understory difference is often explained by variations in stocking per acre during the early years of the rotation.

THINNING

The ideal spacing for young Virginia pine stands is one that permits rapid growth either until the first commercial thinning is made, or until the time of final harvest. Because of the shallow-rooted habit of Virginia pine, most foresters are reluctant to thin, and many valid reasons can be advanced to forego thinning.

Since Virginia pine in most parts of its range is considered primarily a pulpwood species, grown for 25 to 35 years and then clearcut, the advisability of thinning can be seriously questioned. During short rotations a thinning would normally take place 7 to 10 years prior to the harvest cutting. This partial cut might well disturb the crown canopy sufficiently to increase its susceptibility to windthrow, glaze damage, and accordion-type falling, due to the loss of adjacent supporting tree crowns.

Virginia pine has been reported to show no marked increase in diameter growth as a result of release after thinning, unless these cuts are made before age 15 (Slocum and Miller 1953). Thus growth response cannot be used to justify a thinning operation. There is some indication, however, that diameter growth responses do occur with Virginia pine on the better loamy soils.

Perhaps one of the greatest objections to thinning on short rotations is that openings in the crown canopy bring in a hardwood understory. These hardwoods might not otherwise be present at the time of the final harvest. Since a hardwood understory increases the cost of the regeneration period, such thinnings must be justified on an economic basis, weighing the income against greater site preparation costs.

However, when Virginia pine is being grown on sawtimber rotations, in those parts of its range where it develops into a tree of sawtimber size, and where other pine species are lacking, perhaps thinning may be practical, desirable and profitable. Such thinnings would take the form of low thinnings, since thinning from below disturbs the main crown canopy the least, and thus does not subject the stand to windthrow.

Low thinnings would remove merchantable material that is dropping into the weak codominant and intermediate crown classes, utilizing these boles before they die. Such cuttings can only be made where markets exist for material of this size. This is why I stress that such thinnings would take place only late in the rotation, when lower-crown-class trees have reached pulpwood size. I feel that low thinnings of this nature would remove no more than 20 percent of the basal area of these stands since heavier removal would result in excessive opening of the main crown canopy, increasing the threat of loss from wind or glaze.

Thinnings at age 30 in forty- to fifty-year-old sawtimber rotations cannot be condemned from the standpoint of bringing in a hardwood understory, since by this time in a sawtimber rotation an understory normally would have invaded even when thinnings are withheld.

FIRE, SNOW AND GLAZE DAMAGE

Fire protection is an essential part of Virginia pine management, since Virginia pines of all ages are susceptible to fire due to their characteristically thin bark. Although there are reports of sawtimber-size Virginia pines withstanding light ground fires, even old-growth trees die readily if heavy accumulations of fuel result in scorching burns.

Wet, clinging, heavy snow and glaze are especially damaging to sapling stands of Virginia pine. Certain stand treatments may be of some benefit in reducing such damage. The age at which snow and glaze damage appear to be most serious happens to coincide with the age that is best for thinning Virginia pine. Opening the canopy by thinning may lead to more sturdy boles and reduce snow interception. On the other hand, thinning may result in greater damage from snow and glaze due to loss of the support of adjacent trees (Fenton 1959). Rushmore (1949) found that damage from ice storms in southern Maryland was about the same for Virginia pine in thinned stands as in unthinned stands. Slocum and Miller (1953), however, reported glaze damage in North Carolina to be much heavier in 24-year-old thinned stands, while unthinned check areas were undamaged. Further study is needed to find forest-management practices that will minimize injury and loss from snow and glaze.

In summary, I feel that correct spacing and stocking are the key to a successful Virginia pine rotation. Stocking of 680 well-spaced stems per acre, from planting, offers sufficient space to permit rapid growth to the end of the pulpwood rotation, or until thinnings can be made in sawtimber rotations.

Although thinnings normally have little place in pulpwood rotations, more research is needed before the practicability of thinnings in sawtimber rotations can be ruled out. Since Virginia pine will stagnate when proper stocking and

spacing is not present, the planting of abandoned fields and cut-over areas should offer great benefits over natural regeneration.

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THE GROWTH AND YIELD OF VIRGINIA PINE

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Abstract. Total yields of Virginia pine increase as site index, age, and density of stocking increase. Thinning to prescribed basal areas significantly affects periodic volume growth and diameter distributions within stands. Maximum volume growth of Virginia pine stands results from high basal areas. Low basal areas produce the greatest number of large trees.

Additional keywords: Pinus virginiana, site index, basal area, thinning.

Virginia pine (Pinus virginiana Mill.) is a large and important component of forest lands in the Interior South. Most of the Virginia pine stands being managed and harvested today resulted from natural seeding on abandoned agricultural lands. Growth and yield of these stands depend on site quality, age of the stands, and degree of stocking. This paper summarizes published information on how these variables are related to the productivity of Virginia pine. It should provide a handy reference for foresters estimating or projecting stand and individual tree volumes.

The paper also presents original data from a study established in the Virginia Piedmont in 1965 to determine the influence of stand density and site index on the growth of Virginia pine. Dense stocking and poor site quality are characteristic of most Virginia pine stands. Site quality is inherent: it does not respond quickly or without considerable expense to cultural treatments. Yet it must be considered in assessing the potential productivity of a stand. Stand density can be controlled and maintained through intermediate thinnings. Density control is a means of distributing growth on a desired number of select stems. Results indicate the density levels and management strategies best suited to produce desired products in Virginia pine stands.

PAST WORK

The literature on growth and yield of Virginia pine is extensive. Two conventional site index classifications (total height of dominant and codominant trees over index age 50 years) have been determined for Virginia pine in the South. Slocum and Miller (1953) constructed a localized site index chart from data collected on the Hill Demonstration Forest, Durham County, North Carolina. Chaiken and Nelson (1959) developed site index curves for the Piedmont on the basis of data collected in Maryland, Virginia, North Carolina, and South Carolina. Sites sampled for Virginia pine in the Piedmont ranged from 50 to 83 feet--95 percent of the plots ranged from 55 to 80 feet. When dominant and codominant trees are not present, site index for Virginia pine in the Piedmont can be predicted from soil variables (Kormanik 1966).

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Slocum and Miller (1953) found that cubic-foot yields for pure stands of Virginia pine increase as age and site index increase. Many stands of Virginia pine originated following wide-spread abandonment of agricultural lands during the 1930's and 1940's. Yields at site index 70 for these 30- to 40-year-old natural stands are between 3,200 and 4,360 cubic feet/acre. Annual growth is equivalent to slightly over 1 cord per acre per year.[2/] Nelson and others (1961) reported cubic-yield estimates of Virginia pine stands of various densities, on different sites, and with varying proportions of total composition in Virginia pine. Yields increased as density, site index, and proportion of Virginia pine increased.

Growth and yield information are also available for individual trees. Warner and Goebel (1963) developed equations and tables for estimating total cubic-foot and bark volumes of small-diameter (0.5 to 5.0 inches) Virginia pine in the upper South Carolina Piedmont. Virginia pine, a thin-barked species, has a high ratio of wood to bark. Nelson and others (1961) developed equations and tables for estimating the merchantable volume outside bark for large (4 to 20 inches) trees. Merchantable volumes in cubic feet (outside bark and inside bark), standard cords, and board feet (International 1/4-inch rule and Doyle rule) are given in the thorough treatise of Virginia pine by Slocum and Miller (1953).

The growth and yield of individual trees are also influenced by site index and stocking. Height growth on site index 70 is about 1.8 feet per year through age 30, slows down slightly between ages 30 and 50, then decreases rapidly after age 50 (Slocum and Miller 1953). Maximum annual height growth reported for Virginia pine was 2.3 feet per year for 16-year-old plantations in Virginia (Kormanik and Hoekstra 1963). Carvell (1966) showed that the average diameter of 6-, 9-, and 13-year-old Virginia pine stands increased as spacings increased. Height growth--generally recognized to be less sensitive than diameter growth to stocking levels--was not affected by spacings.

THE VIRGINIA STUDY

Methods

The objective of the Virginia study was to determine the response of individual trees as well as stands to varying levels of site index and controlled density.

Fifty-four 1/10-acre plots of Virginia pine were located in Buckingham and Cumberland Counties in the Virginia Piedmont. All stands originated from natural seeding on abandoned agricultural lands. There had been no previous cutting in the stands, and only a few hardwoods and other pine species were present. All trees were numbered and their identities maintained throughout the study. Measurements included diameter, height, and age of individual trees, basal area of the stand, and site index. Cubic-foot volume of individual trees was calculated from the equation developed by Nelson and others (1961). The means and ranges of conditions measured on these plots were:

[2/] Converting factor (solid to stacked measure), 90 cubic feet = 1 cord.

Variable	Mean	Range
Site index at age 50	67	47 - 79
Number of trees/acre	823	340 - 281
Basal area/acre (square feet)	125	75 - 188
Volume/acre (cubic feet)	2070	231 - 3919
Average d.b.h. (inches)	5.4	2.7 - 7.2
Average height (feet)	42	27 - 50
Average age (years)	26	23 - 29

Plots were assigned to residual basal area classes ranging from 40 through 180 square feet/acre within site index classes 50, 60, and 70. Individual plots and surrounding buffer areas were thinned to their prescribed basal areas in 1965 and 1970. Thinning was from below. Hardwoods and other pine species were removed first if possible. Emphasis was put on an equal distribution of residual trees within the study plots. Measurements were made before thinning, after thinning, and again in 1976, 11 years after the study was established.

Results

Site Index

The average stand and individual tree characteristics of the study plots are given for the three site index classes in table 1. Site index influences all dependent variables. Total volume at age 26 ranged from 957 cubic feet/acre at site index 50 to 2,868 cubic feet/acre at site index 70--a three-fold increase in early production. Individual stem diameter and volume increased significantly as site index increased (fig. 1 and 2).

The greatest periodic volume growth after the 1965 thinning occurred at the highest site index (table 2). There was no significant difference in growth among the three site index classes after the 1970 thinnings. Total volume growth over the 11-year period was also nonsignificant among the three site index classes. Periodic annual growth after thinning--ages 26 through 37 years--averaged approximately 142 cubic feet/acre. This is equivalent to 1.6 cords of growth per acre per year, twice that produced prior to thinning.

Total yield (thinned material plus standing volume at age 37) increased significantly as site index increased (fig. 3). Total production at site index 50 was 2,461 cubic feet/acre compared to 4,516 cubic/acre at site index 70.

Stand Density

Stand density had a strong influence on the growth and yield of Virginia pine. Periodic growth increased with increasing levels of basal area (table 3). Total periodic growth at residual basal areas of 140 square feet/acre averaged 2,092 cubic feet/acre. Annual periodic growth from age 26 through 37 was equivalent to approximately 2.1 cords of wood per acre. This is exceptional growth for Virginia pine and almost triple that produced at basal areas of 40 square feet/acre.

Table 1.--Stand and individual tree characteristics of Virginia pine as related to site index.

Site index class and year	Age	Stand: Basal area	Stand: Stems	Stand: Volume	Individual tree [a]: D.B.H.	Individual tree [a]: Total height	Individual tree [a]: Volume
	yr.	sq.ft./acre	No.	cu.ft./acre	in.	ft.	cu.ft.
Class 50							
1965							
Before thinning	26	110	1,350	957	3.9	32.6	0.55
Thinned		31	500	196	3.4	31.3	.29
1970							
Before thinning	31	98	780	1,375	5.0	40.3	1.97
Thinned		20	260	164	4.1	38.3	1.11
1976 (final)	37	95	500	2,102	6.3	47.5	5.09
Class 60							
1965							
Before thinning	26	110	620	1,809	5.7	40.8	2.85
Thinned		25	150	418	5.4	39.6	1.83
1970							
Before thinning	31	99	420	2,026	6.7	48.6	5.35
Thinned		17	90	212	5.5	46.3	3.15
1976 (final)	37	102	330	2,729	7.8	55.2	8.47
Class 70							
1965							
Before thinning	26	144	720	2,868	6.0	47.9	3.86
Thinned		46	250	878	5.6	46.5	3.02
1970							
Before thinning	31	111	440	2,727	7.2	56.3	7.15
Thinned		15	90	330	6.4	55.3	5.48
1976 (final)	37	107	350	3,300	8.3	62.3	10.38

[a] Average of all trees.

Independently, site index and stocking influenced the periodic growth of Virginia pine. We found no clear relationship, however, between the interactions of site index and basal area on growth (fig. 4). This is quite unlike the significant interactions between site index and basal area found for periodic growth of loblolly pine (Nelson and Brender 1963).

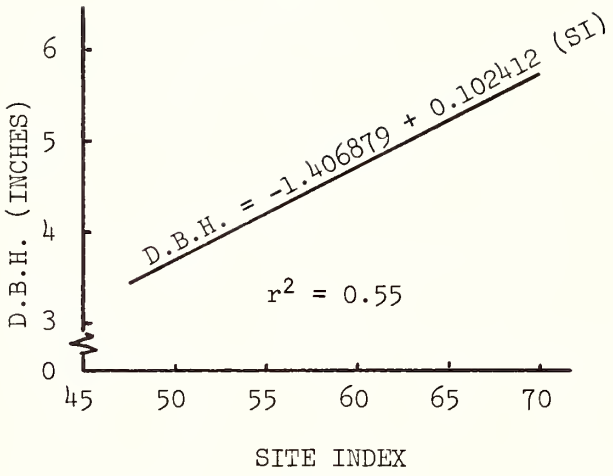

Figure 1. Relationship between site index (SI) and average d.b.h. of 26-year-old Virginia pine stands.

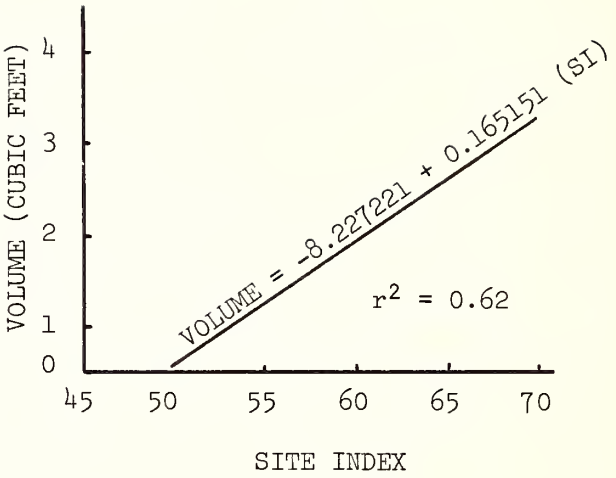

Figure 2. Relationship between site index (SI) and volume of individual trees in 26-year-old Virginia pine stands.

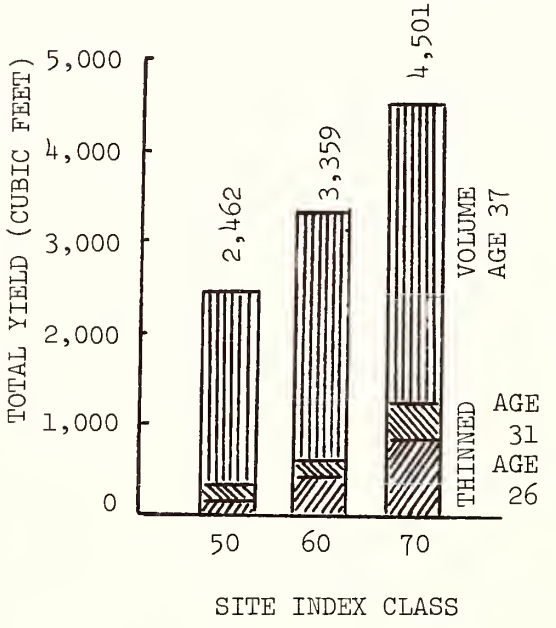

Figure 3. Relationship between site index and yields of 37-year-old thinned stands of Virginia pine.

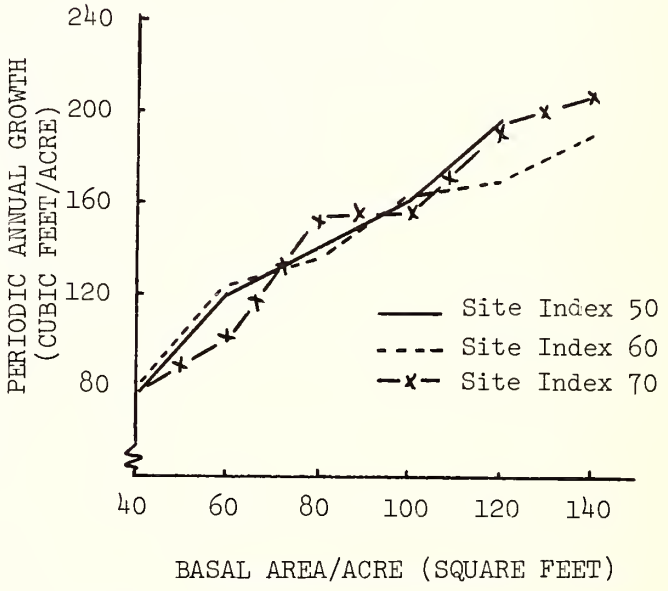

Figure 4. Interaction of basal area and site index on the periodic growth of Virginia pine.

Table 2.--Periodic volume growth of Virginia pine as related to site index.

Period (years)	Site index class 50	60	70
	cubic feet/acre [a]		
1965 - 1970	614 a	635 a	737 b
1970 - 1976	890 a	911 a	907 a
Total	1,504 a	1,546 a	1,644 a
Periodic annual	137 a	141 a	149 a

[a] In each row, values not designated with the same letter are significantly different at the 0.05 level by Duncan's New Multiple Range Test.

Total yield was also related to stand density (fig. 5). The highest volumes occurred at the highest basal areas. Total volume produced at the 180 basal area class was 5,958 cubic feet/acre compared to 2,684 cubic feet/acre for basal area class 40.

The growth of individual trees was also influenced by stand density. Diameter and stem volumes in the 26-year-old unthinned stands decreased as number of trees increased (fig. 6). There were no significant relationships between diameter size or volume of individual trees and basal area of the unthinned stands. The greatest diameter growth occurred after thinning to the lowest basal area classes.

As expected, basal area control affected the diameter distribution of the plots 11 years after establishment. The plots with high basal areas had many trees of relatively small diameters, whereas low-density plots of 60 to 80 square feet/acre had the largest number of trees greater than 10 inches in diameter (table 4). Thus, growth and diameter distributions at the different basal areas help provide guidelines for thinning Virginia pine stands.

Thinning

When to thin Virginia pine stands has been debated among forest managers for many years. Miller (1951), Bramble and Byrnes (1953), and Williamson (1953) have tested the effects on thinning of this species. They reported significant responses to the precommercial thinning of 5- to 8-year-old stands. Growth of residual stems, number of merchantable stems (5 inches d.b.h. and larger), and volume of merchantable stems were greater on thinned than on unthinned plots. Miller (1951) concluded that poor growth response and the hazard of sleet and

Table 3.--Periodic volume growth of Virginia pine as related to residual basal area classes.

Period (years)	Basal area classes (square feet/acre)							
	40	60	80	100	120	140	160	180
	cubic feet/acre [a]							
1965 - 1979	445 a	499 ab	619 bc	736 c	831 c	1,018 d	875 cd	1,194 d
1970 - 1976	396 a	732 b	960 c	1,034 cd	1,190 d	1,074 cd	1,115 cd	845 bc
Total	841 a	1,231 b	1,579 c	1,770 c	2,021 cd	2,092 d	1,990 cd	2,039 cd
Periodic annual	76 a	112 b	144 c	161 c	184 cd	190 d	181 cd	185 cd

[a] In each row, values not designated with the same letter are significantly different at the 0.05 level by Duncan's New Multiple Range Test.

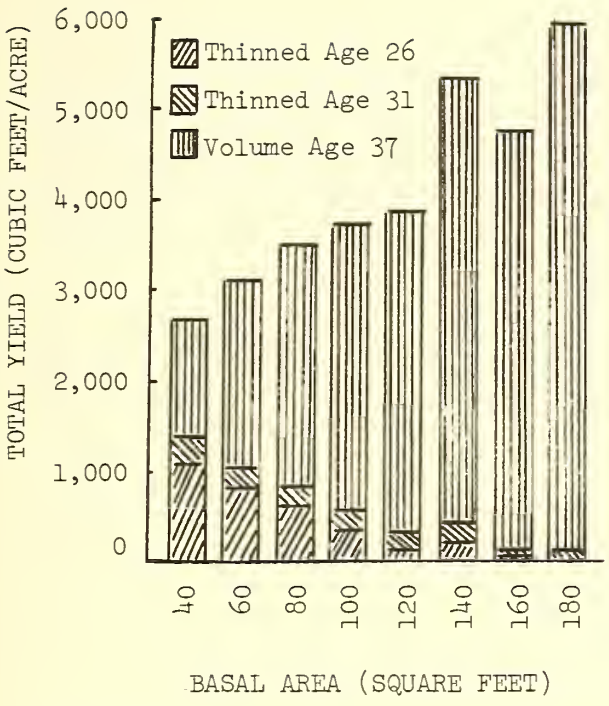

Figure 5. Relationship between basal area and yields of 37-year-old thinned Virginia pine stands.

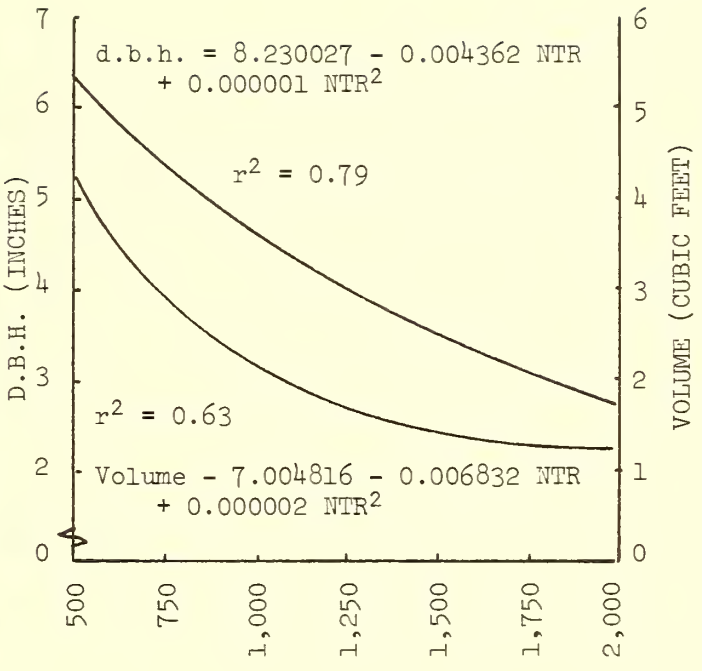

Figure 6. Relationship between number of trees/Acre (NTR), average d.b.h. and average volume of individual trees in 26-year-old Virginia pine stands.

Table 4.--The influence of stand density on the diameter distribution of 37-year-old thinned Virginia pine stands.

Diameter (inches)	Basal area (square feet/acre)							
	40	60	80	100	120	140	160	180
	No. of trees/acre							
≥ 5	108	200	270	330	433	480	510	590
≥ 8	70	99	124	154	83	133	160	170
≥ 10	27	50	62	28	20	22	10	10

wind damage make it impractical to thin old-field Virginia pine stands 12 years and older in the North Carolina Piedmont. Thinning in stands 5 to 6 years old resulted in accelerated growth without sleet damage. Hoekstra and Hutchinson (1963) showed significantly larger diameter growth for released trees than for check trees in age classes ranging from 10 to 29 years. Their results were based on the response of individual trees. One objective of our stand density study was to test the response of 23- to 29-year-old stands to thinning.

Maximum volume growth of Virginia pine stands resulted from high basal areas. Thinning is not recommended when high yields of wood fiber are the objective of management. Thinning did, however, influence the growth response of individual trees. Maximum number of trees 10 inches d.b.h. and larger resulted from low basal areas. The objective in this case would be solid-wood products as well as pulpwood from thinning. Moderate to heavy thinnings will reduce total volume yields below those of densely stocked stands. Economic returns from resulting saw logs may justify the sacrifice of total cubic-foot volume and other expenses incurred in stand density control.

DISCUSSION AND SUMMARY

Virginia pine is a vigorous pioneer species on abandoned agricultural lands and disturbed sites. Dense stocking and low-quality sites are characteristic of most natural stands. Early volume growth of Virginia pine stands increases as stocking and site quality increase. The influence of site index on growth appears to lessen as stands reach maturity. Growth response at this stage is primarily a function of basal area.

We found no clear relationship between the interactions of site index and basal area on the periodic growth of Virginia pine. This finding is quite different from the significant interactions between stand density and site index reported for loblolly pine. Several reasons may account for this difference. First, the stands were thinned at 26 years; perhaps these trees were too old to respond to stand manipulation. Tree crowns in heavily thinned Virginia pine plots did not appear to respond to reduced competition as rapidly as do loblolly pine. Second, 11-year treatment period may be too short for interactions to express themselves. A third reason may be that the range in site index from 50 to 70 is too narrow to measure interactions accurately.

Research indicates that these stands can be managed for products with high economic returns to the landowner. Virginia pine, like other pine species, produces the greatest cubic-foot volumes at the highest densities on the best sites. Basal areas should be maintained at 100 square feet/acre or greater if the management objective is high yields of wood fiber. Thinning provides the means to distribute growth on a selected number of desirable stems. For production of small saw logs by age 40, we recommend that basal areas be maintained at 60 to 80 square feet/acre. The stand density study was initiated well after tree crowns had closed. The best management strategy, however, would be to thin before age 15 with subsequent thinnings as needed. Live crown ratio of individual trees should be at least 40 percent to ensure continuously rapid growth. Heavy thinning should be avoided in areas subject to severe wind and ice storms.

Virginia pine accounts for a substantial portion of wood fiber presently being harvested in the Interior South. Much of the supply comes from medium- and low-quality abandoned agricultural lands that seeded in naturally. Little money or energy was invested to obtain these stands. Results were fortuitous. In the future, satisfactory supplies of wood and wood fiber from Virginia pine will require careful and directed forest management.

ACKNOWLEDGEMENT

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SOME IMPORTANT DISEASES OF THREE EASTERN PINES

William H. Sites

ABSTRACT

Shortleaf (Pinus echinata) and Virginia pine (Pinus virginiana) are both relatively disease free when compared to eastern white pine (Pinus strobus). The most serious disease of shortleaf is littleleaf disease with pitch canker, caused by Fusarium moniliforme var. subglutinans, causing serious damage in some areas. Above 3,000 feet elevation, blister rust caused by Cronartium ribicola, can be quite damaging on white pine. Eastern gall rust, caused by Cronartium cerebrum, and pitch canker are the most serious stem diseases on Virginia pine. All three host species are susceptible to annosus root rot caused by Fomes annosus and red heart caused by Fomes pini.

INTRODUCTION

Shortleaf, Virginia and white pine are affected by a variety of diseases. Some they have in common, while others are more serious on some hosts. Because of time limitations, I will discuss only those diseases that cause the most severe losses.

Shortleaf Pine (Pinus echinata)

Shortleaf pine is not affected by many of the common conifer diseases. It is not severely affected by ice, wind and sudden temperature changes (Hepting, 1971).

The most serious disease of shortleaf is littleleaf disease. It is a non-infectious disease that generally affects trees 20 years of age and older (Zak, 1957). Affected trees occur in groups or over large areas. The disease is common on infertile soils of poor internal drainage and aeration. The fungus Phytophthora cinnamomi is associated with the roots of diseased trees. It has also been suggested that nematodes may contribute to the problem (Ruehle, 1962).

Trees affected by littleleaf have yellowish, short needles and decreasing annual shoot growth. In addition, because of reduced growth and loss of needles, the remaining foliage appears to be concentrated at the ends of the branches.

There is little control for littleleaf, once it is established. It is caused by soil conditions that can only be alleviated by improving soil fertility and structure. Control can be obtained by managing for resistant species such as white pine, hardwoods or through the development of resistant shortleaf stock.

Although we first think of littleleaf when we consider diseases of shortleaf, there are others as important. One of them is the pitch canker disease caused by the fungus, Fusarium moniliforme var. subglutinans. Although pitch canker on shortleaf has been known for some time (Hepting and Roth, 1946), it did not seem to be particularly aggressive. However, in 1973, we found 20- and 30-year-old shortleaf stands in eastern Tennessee being killed by the pitch canker fungus. The trees initially had a dieback which became severe enough to cause mortality.

Two symptoms were common. The first was the heavy resin flow on stems. The second was branch tip mortality with pitch soaking of the wood in and under the bark where healthy changed to dead branch.

The recent outbreaks of pitch canker in several species of pine has caught us off guard. At the present time, there is no good explanation for the rapid spread in some areas and no known control in forest stands. The disease does seem to be cyclic, causing severe damage one year and none the next.

One major heart rot fungus (F. pini) is common on shortleaf. It is usually most serious on overmature trees and in addition to rendering the wood nearly useless, can cause failure in trees in recreation areas.

Several root and butt rot fungi have been described on shortleaf. Most are not serious overall but cause occasional, localized losses. Fomes annosus, although less serious than on some other species, does attack shortleaf. The best control is to apply borax to freshly cut stump surfaces during first thinnings. Normally, we think of shortleaf growing on clay soils of the type not usually considered high hazard for annosus root rot. However, a check of other stands in the area may be helpful in determining the availability of F. annosus inoculum. A new booklet published in 1977 contains an excellent discussion of annosus root rot (Froelich, et. al, 1977).

There are few problems associated with the foliage of shortleaf. As we will see, this is a sharp contrast to eastern white pine.

Eastern White Pine (Pinus strobus)

While shortleaf and Virginia pine are fairly hardy and resistant to many conifer diseases, eastern white pine is not. It is prone to a long list of root, butt, stem and foliage diseases.

One serious stem disease is white pine blister rust caused by the fungus, Cronartium ribicola. Introduced into this country on our own white pine that was germinated and grown in European nurseries, this disease is one of the most limiting factors to the growth and management of white pine in high hazard sites above 3,000 feet elevation.

Control is very difficult and may eventually be accomplished most successfully with the use of resistant planting stock. Attempts to remove the alternate host, ribes have been largely abandoned around forest stands. Only around Christmas tree plantations, where a high value crop is being managed, can ribes be removed economically. Some control can be obtained by pruning off cankers before they reach the main stem.

Fomes pini is a serious trunk rot in white pine. In recent years, we have found it to cause serious hazards in old growth trees in recreation areas.

Root rots are common in white pine. This species is particularly susceptible to infection by Fomes annosus. Again, spread can be quite rapid after first thinnings but can be controlled with borax. Polyporus schweinitzii is very damaging and often enters basal wounds such as those caused by fire. Armillaria mellea is both a saprophyte and a parasite. It can be very destructive in areas converted from hardwoods. Old stumps provide a base from which the fungus moves out to contact pine seedlings and saplings. Normally, losses from A. mellea are about 1 percent per year for the first 10 years on an area with a lot of hardwood stumps.

White pine root decline, caused by Verticicladiella proceri, can cause serious losses. The disease is more severe in planted stands on wet sites. In severe cases, it kills 1 to 2 percent for the first 25 years. Mortality is random and serves as a thinning agent in forest stands, but can cause severe losses in high value stands. The best method of control is to manage for other species.

There are many agents which affect white pine foliage. Hepting (1971), provides a long list of fungi that are known to be damaging. However, there is no effective control under forest conditions.

Air pollutants can be as damaging to white pine foliage as fungi. White pine is sensitive to ozone, sulphur dioxide, chlorine, fluorine and many more. The most common symptoms are needle tipburn, stunting of needles and loss of older needles. There is little control for this type of damage except in the case of Christmas tree plantations. Although some of these materials turn up in remote areas, the prudent grower would locate his plantings away from electric generating plants, ore smelting plants, and other large industrial complexes.

Virginia Pine (Pinus virginiana)

Virginia pine is a fairly hardy species and generally free of diseases. I will not go back through the details of each disease, but I will mention here those diseases that are common to it. A complete review would only duplicate segments of the discussions on shortleaf and white pine.

Virginia pine is susceptible to F. pini and the pitch canker disease. In the case of the latter, pitch soaking of the wood is a common characteristic (Berry and Hepting, 1959).

Eastern gall rust (Cronartium cerebrum) is very common and produces round galls on the trunk or lateral branches. It can reduce tree form and

open larger stems to decay. There is little control under forest conditions. In Christmas tree plantings, diseased limbs can be removed.

Fomes annosus and P. schweinitzii are both problems on roots and butts of Virginia pine. Control measures would be similar for the previous species.

Several species of the fungus, Coleosporium, attack Virginia pine foliage (Hepting, 1971). However, there is little effect on infected trees.

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INSECT CONTROL IN THE MANAGEMENT OF THREE MAJOR PINES OF THE INTERIOR SOUTH

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ABSTRACT

Insect caused losses to pine forests of the interior south must be reduced if we are going to meet future wood resource demands. With intensive forest management of shortleaf (Pinus echinata Mill.), Virginia (P. virginiana Mill.) and eastern white pine (P. strobus L.) insect caused product degrade, understocked stands and control costs become more important to the land manager. A practical approach to control would be prevention through forest and land management practices. Each silvicultural action or other factors like site preparation and site-species relationship could enhance or deter insect activity. However, it may often be necessary to use integrated control measures.

INTRODUCTION

Economically and environmentally speaking, the control of insects affecting the pine resource of the south has never been more important than it is today. This is because of the projected needs for wood products and other forest resources (recreation, camping, fuel, water, etc.) and the high value of pines as ornamentals, shade and Christmas trees.

The cost of applied chemical control has increased tremendously in forestry due to the cost increases of chemicals, labor and application equipment during the last 10 years.

Another important factor we are facing in timber and land management is the effects of chemical control on our resources (water, wildlife and fisheries). We also have to consider the increased costs of dealing with the numerous environmental groups, public reviews and environmental impact statements required for these control projects.

There are a number of insects that damage or destroy pines of the interior south from outplanting until harvest. The most practical approach to management of these insects is through prevention. This includes utilizing good management, harvesting, and other practices in the forest complex that will maintain timber stands in a condition unfavorable to insect development.

Principles of good silvicultural/insect relationships from which to

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develop and implement good pest management practices to prevent or reduce insect losses to acceptable levels have been outlined by many notable entomologists (Graham, 1952) and the experience of researchers elsewhere are available (Craighead, 1942; Graham, 1959; Morris, 1951; and Prebble, 1951) (Drake, 1974). Foresters, entomologists, and other workers have reported certain clues to silvicultural controls which are supported by repeated observations. These were summarized by Bennett (1965) and are now being researched by scientists in the Expanded Southern Pine Beetle Research and Applications Program. Many of the individual studies are showing success in beetle management through silvicultural practices. Beetle activity may also be predictable by stand hazard ratings now being developed by the program.

Prevention is not always the answer and outbreaks may occur regardless of precautions taken. When this happens, direct control measures may be the only recourse. If this is so, we should consider the possibility of integrated pest management. Integrated pest management is the use of any combination of two or more of the following: chemical, biological, mechanical, species site relationship, timing of application, the use of resistant hosts, or other control practices available to the land manager.

The following are some of the more important insects affecting the three major pines of the interior south and suggestions for control through management practices where applicable.

Reproduction Weevils

Reproduction weevils, the pales weevil, Hylobius pales (Herbst.), and the pitch eating weevil, Pachylobius picivorus (Germar) are the most serious pests of pine regeneration. Of these two weevils, the most important to the pines of the interior south is the pales weevil. Reports throughout the south incicate that this weevil accounts for 20 to 30 percent of the mortality of pine seedlings planted in recently cutover pine lands.

These insects are attracted to the odor of fresh pine resin and are drawn into any area where pine is being cut. They feed on the pine debris and slash left from logging or other site disturbances before mating and laying eggs.

The adult weevils lay their eggs in pine debris underground and stumps and roots between March and October. Areas cut in cooler months will attract adults longer than those harvested in summer months. Eggs may be laid at different times in the same stump resulting in overlapping generations. This insect has two generations per year.

Damage to seedlings usually occurs in the spring when the overwintering adults emerge and begin to feed. Most of the heavy damage is caused by the overwintering adult population. Damage can be incidental feeding on seedlings causing pits in the bark; when feeding is heavy the pits merge and girdling of the stem takes place. Feeding may be so heavy in the spring that all of the bark is removed from the seedling. This usually occurs because the planted seedlings are the only suitable material available to the weevils.

If seedlings are planted the following winter on sites which were cut or site prepared after June, the overwintering adults can heavily attack the seedlings the following spring.

In areas that have been logged and/or site prepared prior to July, there will be no serious damage to seedlings planted the following winter.

Therefore, by adjusting silvicultural practices the pales weevil can be controlled through management practices. A 9-month delay in replanting in cut-over or disturbed pine forests will all but eliminate damage from these insects. Areas must be cut and site prepared prior to July of the preceding year for this method to be effective. Where this cannot be practiced, Forest Insect and Disease Management should be contacted for the proper applied or integrated control procedures.

The following can be used to hazard rate pine areas:

Harvest Date	Site prep date cords left standing	Site Hazard	Recommendation
Prior to June	Prior to June	None	Plant pines Nov.-Mar.
	After June (Less 5 cord/acre)	None	Plant pines Nov.-Mar.
	(Over 5 cord/acre)	Low - Moderate	Plant pines the following year/ or contact insect control specialist
After June	After June	Low to high	

Pine Tip Moths

Three species of pine tip moth effect the pines of the interior south. They are the Nantucket pine tip moth, Rhyacionia frustrana Comstock, which prefers shortleaf pine but will attack Virginia pine. The European pine shoot moth, R. buoliana (Schiff.) which attacks Virginia and eastern white pine. And another pine tip moth R. rigidana (Fern.) is commonly found damaging Virginia pine.

The tip moth larvae feed on buds and twigs of young pine in natural stands and plantations. The moths overwinter as pupae in the tips of infested trees. The adults emerge on warm days during the late winter months, mate, and lay eggs in the axils between the needles and stem near the terminal bud on the new shoots of host trees. When the eggs hatch, the larvae bore first into the base of developing needles and later into the new terminals or buds. There are approximately two to four generations per year.

These insects are so widespread that not many nurseries or young stands are free from attack. Before outplanting, seedlings should be inspected and injured buds and twigs pruned well below the dead margin on the stem, because larvae are usually feeding in the green tissue. When a heavy infestation of tip moths occur in a stand, trees can be severely stunted or deformed.

The incidence of tip moth occurrence is usually directly related to the vigor of the young pine stands. Areas with a history of heavy tip moth activity should be avoided when shortleaf pine was the residual species and is to be replanted there. In an area with these characteristics, vigorous tree strains such as superior tree seedlings or resistant strains will help reduce damage.

Site improvement can also help if there is an area close by harboring infested weakened trees. Such areas could be barren soils along roadsides and other spoil banks common throughout the south. Trees in this condition serve as focal points for the spread of an infestation into relatively healthy stands. These trees should be cut and burned, if possible.

Weyerhaeuser's research has concentrated on trying to determine the effect of different site preparation techniques on tip moth damage and the rate of parasitism and to determine if an aerial application of a pesticide would provide satisfactory control. Site preparation was found to have a significant influence on the tip moth population. Mechanically site prepared areas had from 1.5 to 4 times the average number of infested tips when compared to chemically prepared areas. In addition, parasites were found to be more active in the chemically prepared areas (Flavell, 1974).

Personal experience and observations by other foresters, entomologists, and various specialists has shown that where some shade is present either from seed trees or light brush, tip moth occurrence seems to be much lighter or not present even on poorer sites that have been planted with light shade.

White Pine Weevil

This insect is usually regarded as the major insect pest of white pine. During late April or early May, adults lay eggs on the terminal shoots of the host trees. Eggs are laid in feeding punctures in the bark. When the eggs hatch, young larvae are found around the terminal feeding as a group down the main stem through the inner bark. Larvae pupate in the pith or wood of the terminal shoot after feeding is complete. Here the pupae transforms into the adult. The young adults do not emerge from the wood until late October and November, and move to overwintering sites usually on the ground at the base of the host tree. This insect rarely causes mortality--only stunting and deformity of the trees where repeated attacks occur.

Damage by the white pine weevil can be reduced by making conditions in a young stand unfavorable for egg laying. Research has shown that the female will only lay eggs within a narrow range of temperature and relative humidity. Techniques involving the use of shade from overstory trees have been developed to produce attack, however, this requires intensive management. In the south, this particular insect is not as much of a problem as it is in the northeast.

Sawflies

Five different sawflies are commonly found on shortleaf, Virginia, and eastern white pine. The Virginia pine sawfly, Neodiprion pratti pratti (Dyar), feeds on the old needles of both Virginia and shortleaf pine. The Arkansas pine sawfly, N. taedae linearis Ross, feeds primarily on older foliage of shortleaf. The pine sawfly, N. excitans Roh., also feeds primarily on the older needles of shortleaf. The white pine sawfly, N. pinetum (Norton), feeds on both the old and new needles of eastern white and shortleaf pine. The redheaded pine sawfly, N. lecontei (Fitch), feeds on both old and new needles of shortleaf and occasionally on white pine and can have up to five generations per year.

The most serious damage to pine is caused by sawflies with multiple generations, feeding in the summer and fall on both old and new needles. This singles out the white pine sawfly and the redheaded pine sawfly which also prefer young trees. The redheaded pine sawfly is capable of killing young trees in one growing season. The white pine sawfly, with only one generation per year, usually takes 2 to 3 years before a population builds up enough to cause mortality. The other sawflies mentioned above usually defoliate larger trees, causing growth loss and occasionally weakening trees enough to make them susceptible to bark beetle attack. The other aspect of sawfly defoliation is the aesthetic losses caused.

Polyhedral virus, hogs, mice, shrews and insect parasites and predators tend to keep populations in check. However, when conditions favoring sawflies exist their populations can expand rapidly causing serious damage almost overnight.

Southern Pine Bark Beetles

The southern pine beetle, Dendroctonus frontalis Zimm., pine engraver beetles, Ips spp., and the black turpentine beetle, D. terebrans Oliv., are the most destructive insect pests of our southern pines. These beetles are capable of rapid population buildups that may result in widespread timber losses if conditions that are favorable for their development occur. One or more of the species can attack pine stands from sapling size to harvest. They kill trees by feeding and constructing egg galleries in the cambial region of the tree which results in girdling. In addition, the southern pine beetle introduces blue staining fungi which hastens the death of the host trees by plugging the water conducting tissue.

The most common factor underlining outbreaks of southern pine bark beetles is poor tree vigor. When unhealthy stands become further weakened by drought, fire, flooding or careless logging, ideal conditions for explosive bark beetle populations are present. This is particularly true with the Ips beetles because this insect is a good indicator of poor vigor in pine stands. Ips will only attack a tree in extreme stress. The black turpentine beetle, however, can attack fairly healthy trees since it is able to withstand the heavy resin flow produced by the attacked tree. The black turpentine beetle is also highly attracted to logging damage and trees stressed by natural climatic factors. The southern pine beetle is by far the most destructive of the southern pine bark beetles, because once a population of this beetle reaches outbreak proportions it can attack relatively healthy stands of pine timber. Each of the southern pine bark beetles readily attack shortleaf and Virginia pine. White pine is not one of the preferred hosts of the southern pine beetle though it is frequently attacked by many of the Ips beetles and the turpentine beetles.

Prevention is the most realistic approach to minimizing timber losses caused by pine bark beetles. This is one way of avoiding the costly short term direct control projects. Prevention can be achieved through sound silvicultural management of healthy timber stands providing sustained growth.

There are several silvicultural or mechanical techniques that can be used to reduce the hazard of bark beetle attack. Harvest heavily stocked and over-

mature stands, maintain stands of healthy fast growing trees, and utilize harvesting practices that minimize stand disturbance.

Some silvicultural practices that promote healthy vigorous stands include:

1. Match Site With Planting Stock. Avoid offsite planting of pine. Use the proper species for the given site.

2. Altering Stand Density. Avoid overstocked stands. An overstocked stand is one in which the growing stock has exceeded 80 percent of full stocking for that area and is dependent on the age, pine species, and site index of the stand. Thinning can be used to keep stands in a healthy rapidly growing state.

3. Remove High Risk Trees. Lightning-struck, diseased, decadent, suppressed and overmature trees can harbor and provide endemic populations with a source of material to build up in. These trees should be removed from stands through sanitation salvage cuttings.

4. Avoid Site and Residual Stand Damage. Mechanical damage to the site and stand should be avoided during logging or thinning. This includes scarring residual trees and soil and root damage. Road building and other activities should also keep damage at a minimum.

5. Forest Activities Should Be Timely. Rotation age is important. Stands should be harvested before they stagnate.

6. Altering Stand Composition. This can be one of the most hazardous of all forest activities. Make sure the site will support pine. If it is a mixed pine hardwood bottom land forest, it may be better to maintain the hardwood.

7. Short Term Practices. Stand vigor can be increased through chemical brush control and controlled burning. When employing these techniques, care must be taken to minimize stand disturbance.

Additional information involving management practices and silvicultural techniques will be available in the near future from studies involved in the U.S.D.A., Forest Service Expanded Southern Pine Beetle Research and Applications Program. As these become available, Forest Insect and Disease Management will be transferring this technology to the land managers. If any additional information on the above-mentioned insects, other insects, insecticides, or other specific insect or disease problems is needed, it may be obtained from your state forestry organization and Forest Insect and Disease Management Field Offices. Forest Insect and Disease Management Field Offices are located at Asheville, North Carolina, Doraville, Georgia, and Pineville, Louisiana.

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MICROTINE RODENTS IN VIRGINIA PINE PLANTATIONS: THEIR ECOLOGY AND MEASURES FOR POPULATION CONTROL

Ralph W. Dimmick [1/]

Abstract.--Prairie vole damage to pine plantations is predominantly by girdling the stems above the root collar. Plantations are susceptible to damage when habitat conditions for the vole are adequate to produce populations of about 80 to 250 animals per ha. Zinc phosphide on grain bait applied at a rate of 11.3 kg bait per ha produced acceptable control.

Additional keywords: microtine rodents, rodenticide, EPA, rodent ecology, Virginia pine.

INTRODUCTION

Rodent damage to Virginia pine (Pinus virginiana) plantations has resulted in locally severe economic losses in Tennessee during the past decade. Particularly significant was the destruction of nearly 1600 hectares of 3 to 5 year old Virginia pine on the Cumberland Plateau during the late 1960's. Concurrently with this destruction, rodents were causing problems in progeny test plantings elsewhere on the Plateau and Highland Rim areas of Tennessee. In all cases Virginia pine was the species heavily damaged, while other pines planted nearby in similar ecological situations were untouched or nearly so.

BIOLOGICAL FEATURES OF THE PROBLEM RODENTS

The principal species causing damage on the Cumberland Plateau was the prairie vole (Microtus ochrogaster), with pine voles (M. pinetorum) implicated in some instances. Elsewhere in the mid-south, cotton rats (Sigmodon hispidus) and meadow voles (M. pennsylvanicus) have caused damage, and in some cases they have attacked other species of pines. Cotton rats are more common in southern and western portions of the South, while meadow voles occur along the Blue Ridge and into northern and eastern United States.

All of the species are principally herbivores, feeding on stems, leaves and roots of herbaceous plants. They occupy the area of interface between soil surface and vegetation, operating in the twilight zone beneath densely thatched vegetation. Pine voles, however, are much more subterranean, while cotton rats are less restricted to dense vegetation than prairie and meadow voles.

Prairie vole biology is reasonably representative of this entire complex (Table 1). They are prolific breeders, reaching sexual maturity in about 6 weeks. In the mid-South, prairie voles breed during all months. Pregnancy rates of 242 females examined during a 12-month period ranged from 23

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percent in December to 92 percent in June, with 55 percent of all females pregnant (Baker, 1971)(Table 1). Mean number of embryos in 134 in utero litters was 3.4; litter size did not vary significantly between months. Females are post-partite breeders, and probably are induced ovulators. They may have several litters per year.

Table 1. Some life history characteristics of prairie voles in Tennessee.

Feature	Value
Weight	40-50 g.
Age at sexual maturity	about 5-6 weeks
Breeding season	continuous
Monthly pregnancy rates	23% (Dec.) to 92% (June)
Litter size	3.4 fetuses
Population densities	up to 250 per ha
Home range size	approx. 0.03 ha
Life span	short (4-6 mo.)
Food habits	herbivorous

Population densities commonly reach 250 animals or more per hectare (Table 1)(Dimmick, 1972; Deitrick, 1970), but densities of roughly 70-80 per ha are sufficient to result in substantial damage to plantations. Life spans are short, averaging less than a year (Deitrick, 1970). Average daily range encompasses an area less than 0.03 ha.

The composite picture, then, is of a species which has a very high reproductive potential, capable of rapidly expanding its population when suitable habitat is encountered.

Perhaps the most significant attribute of prairie voles relevant to the problem of damage to pine plantations is their apparent strong attraction to Virginia pines. It is obvious that the cambium of pines is not essential to their welfare, as high populations occur in habitat with no woody species. Yet when Virginia pine is available in otherwise suitable habitat, it is fed on extensively as though it were, in fact, a requirement for life.

CHARACTERISTICS AND DETECTION OF DAMAGE

Plantations are susceptible to damage as long as the understory remains habitable for the voles. This may be as soon as planting, when trees are

planted in established sod, or within 2 to 3 years after planting when mechanical site treatment is employed. The plantation remains susceptible until crown closure provides deep shading, eliminating most of the understory grasses.

Damage to the pines is principally girdling of the stem just above the ground, with some feeding on roots. In contrast, pine voles feed principally on the roots. Because of the secretive nature of voles, and the time lag between the initiation of girdling and yellowing or death of the trees, substantial damage can occur before it becomes noticeable by casual inspection of the plantation.

Late summer through winter seems to be the period when damage levels are greatest (Table 2). Intensity of damage probably reflects both the population density of voles and the uniformity of vole habitat, features which themselves are obviously related. Mortality of trees may occur as scattered singles or clusters of varying sizes; occasionally large patches within the plantation may be deforested.

Table 2.--Characteristics of vole damage to Virginia pine on two experimental plots on the Cumberland Plateau, 1969.

	Date	Percent Damaged	Amt. of Girdling (% of those damaged)			
			<¼	¼ to <½	½ to <Comp	Comp
Plot 69 A	Nov. 18	19.4	63.2	15.8	21.1	0
	Nov. 24	25.8	52.0	20.0	28.0	0
	Dec. 5	28.7	50.0	21.4	28.6	0
	Dec. 10	29.7	49.8	21.7	29.1	0
Plot 69 B	Nov. 18	35.7	54.3	40.0	5.7	0
	Nov. 24	37.8	45.9	37.8	13.5	2.7
	Dec. 5	38.8	41.1	38.3	20.7	0
	Dec. 10	28.9	42.0	39.4	23.5	0

The presence of voles in an area can be determined rather simply by inspection of the soil surface. Narrow tunnel-like pathways are the most easily observed sign. Freshly cut stems of grass and fecal droppings in the runways will further document their presence. The occurrence of damage

can be substantiated by pulling back the vegetation from the base of trees to look for girdling, first examining trees within dense patches of grass. Bare reddish areas on the trunk with clear, sticky sap have probably been done within the past few days.

REDUCTION OF VOLE POPULATIONS

Reduction of the vole population may be accomplished by two general approaches: (1) alteration of habitat, and (2) direct reduction of the animal population. The first approach may be most desirable for small intensively managed areas. The effective approach would involve removing the herbaceous cover which supports the vole population, thus reducing vole numbers and their access to the trees.

The second approach may be most feasible when damage is occurring over large areas of less intensively managed plantations. A number of poisons are effective, though many are particularly hazardous to non-target species, and are long lasting in the environment. Consequently, most of these are not registered for use in the forest environment. One material which is registered by the Environmental Protection Agency (EPA), and which is effective is zinc phosphide, usually applied to a grain bait in a concentration of 2 percent by weight. The grain usually used is cracked corn, although oats are an effective alternative. I applied zinc phosphide on oats during early winter on the Cumberland Plateau, and found it to be an effective rodenticide when broadcast at a rate of about 11.3 kg of bait per hectare (Table 3)(Dimmick 1972).

Table 3.--Number of prairie voles captured prior to and following experimental treatments in two Virginia pine plots on the Cumberland Plateau, 1970.

Date	Treatment		
	Prolin tubes	Zinc phosphate	Control
Pre-treatment			
September	35	--	44
October	30	50	49
November	28	39	36
Mean	31.0	44.5	43.0
Post-treatment			
November 17-20	4[a]	7	35
December	0	9	19
Mean	2.0	8.0	27.0

[a] Two of these animals died in live trap. Cause of death appeared to be internal hemmorhage, symptomatic of anticoagulant poisoning.

Reduction in vole numbers can be expected to last only one year, however, if habitat conditions remain attractive to the voles. Consequently, treatment may need to be repeated annually if examination of the plantations in late summer determines that vole populations have recovered from the previous year's control effort.

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ALTERNATIVE METHODS OF REGENERATING WHITE PINE IN SOUTH CAROLINA[1/]

D. H. Van Lear and S. K. Cox[2/]

ABSTRACT

Five years after planting, white pine (Pinus strobus L.) seedlings in clearcut plots were about 30 to 50 percent taller than those underplanted in residual hardwood overstory plots. Seedling diameter in clearcut plots was significantly increased by controlling stump sprouts with herbicide. The residual overstory trees partially reduced both numbers and height of competing woody vegetation, but also slowed growth of white pine seedlings. Growth rates of residual overstory trees during establishment of the underplanted pine were greater than trees in an uncut portion of the stand. Visual impacts of clearcutting and planting versus underplanting must be evaluated over the entire regeneration period.

INTRODUCTION

Many, perhaps most, hardwood and mixed pine-hardwood stands in the southern Appalachian and Piedmont provinces are of poor quality. A number of factors have contributed to this lack of quality. Foremost among these is the practice of high-grading whereby the best stems of the better species are periodically removed. Removal of the larger trees throughout the stand has resulted in logging damage to residual trees, as well as failure to establish regeneration of desired species. Continuation of this type of logging creates a stand dominated by defective trees of undesirable species.

In many cases, the forester wants to convert these poor quality stands to pine, or at least to stands with a large component of pine. The most commonly practiced technique of stand conversion is clearcutting followed by site preparation and planting a suitably adapted pine.

Sometimes a more gradual conversion may be desirable. Areas which are especially sensitive from either an aesthetic standpoint or because of site conditions might be more effectively converted by planting pine beneath a partially cut hardwood overstory. Once the pine was successfully established and had reached the desired height, then the residual hardwood overstory could be removed. In the evaluation of such a cultural treatment, many factors would have to be weighed, such as growth and species composition of the new stand, as well as the cost of the conversion technique.

To withstand the shaded conditions under the residual hardwood overstory, the pine species chosen for underplanting would necessarily be relatively shade-tolerant. White pine (Pinus strobus L.) would lend itself ideally to this situation since it establishes itself naturally under hardwood overstories (Wilson and McQuilken, 1963).

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Underplanting of white pine has been successful in the northern part of its natural range (Gatherum et al., 1963; Wendel, 1971; Logan, 1962; Clements, 1966). In South Carolina, underplanted white pine that were severely suppressed for 20 years responded to release from a heavy hardwood overstory (Goebel and Cool, 1968).

The purpose of this study was to compare growth and survival of white pine seedlings planted beneath a residual hardwood overstory to that of seedlings planted in a clearcut, with and without herbicidal control of hardwood sprouts. The effects of these treatments on hardwood competition and growth of residual overstory trees was evaluated. The data reported represents results five years after the study was initiated.

METHODS

The experiment was installed on the Clemson Experimental Forest in the Upper Piedmont of South Carolina. The study area initially consisted of an uneven-aged stand of upland oaks, hickories, and scattered yellow poplar (Liriodendron tulipifera L.) and shortleaf pine (Pinus echinata Mill.) ranging in age to 100 years. Basal area averaged about 30 m^2/ha.

The study was laid out in a 2 x 2 split-plot randomized complete block design with three replications. Clearcutting and planting versus planting under a residual overstory constituted the main treatments, while the secondary treatment consisted of the presence or absence of herbicidal control.

The hardwood stand was logged during late summer and winter of 1973. One half was clearcut and the other half was cut to a residual basal area of about 8 m^2/ha. Residual trees were in the dominant or codominant crown classes and were selected for their high-value growth potential, as well as distribution to furnish the desired shade. Both areas contained six plots, each 46 x 31 m. Half of each plot received herbicidal control of hardwood sprouts. White pine seedlings (2-0) obtained from the South Carolina Forestry Commission nursery were hand-planted at a 2 x 2 m spacing during mid March, 1974. Stumps were directly sprayed to saturation with a 1:19 mixture of 2,4,5-T and diesel oil on designated plots.

Height and diameter of white pine seedlings at ground line were measured following the fifth growth season after overstory trees were removed. All seedlings were measured on the residual overstory plots. On clearcut plots, because of the density of competing vegetation, every fifth seedling was measured. Competing woody vegetation present five years after the treatments were installed was tallied on four 0.025 ha sub-plots of each major plot. Total stems/ha and average height by species were determined. The effectiveness of herbicide on preventing stump sprouting was evaluated by counting sprouts on 180 tagged stumps.

RESULTS

After five growing seasons, white pine seedlings were significantly taller in the clearcut plots than in the residual overstory plots (Table 1). Total height of seedlings in clearcut-sprayed plots averaged 56 percent

greater than that of seedlings in the residual overstory-unsprayed plots, and 16 percent greater than that of seedlings in the unsprayed clearcut plots. Spraying hardwood sprouts in the residual overstory plots had no effect on total height of white pine seedlings.

Table 1. Average height, diameter, and survival percentage of white pine seedlings five growing seasons after planting.

Treatments	Height	Diameter at Ground Line	Survival
	(cm)	(mm)	(%)
Clearcut-sprayed	151 a*	23 a	38 a
Clearcut-unsprayed	130 b	18 b	48 a
Residual Overstory-sprayed	101 c	16 b	52 a
Residual Overstory-unsprayed	97 c	13 b	41 a

* Means followed by the same letter are not significantly different at the 5 percent level.

Average diameter of white pine seedlings was largest in the clearcut-sprayed treatment (Table 1). Average diamter of seedlings in the clearcut plots where competition was not controlled did not differ significantly from that of the residual overstory plots.

Survival rates after five growing seasons and following removal of overstory trees ranged from 38 to 52 percent among the treatments (Table 1). The overall survival rate after two growing seasons was 49 percent, so little mortality has occurred over the three subsequent years. A long dry period immediately following planting accounted for the relatively high rate of mortality. White pine generally would be expected to have higher survival rates in this area.

Removal of the residual overstory trees resulted in some damage to the 5-year-old white pine seedlings (Table 2). About 20 percent of the seedlings experienced damage to varying degrees. However, only six percent were killed outright or were expected to succumb from the logging activity.

Table 2. Damage to white pine seedlings by removing the residual overstory five growing seasons after planting.

Damage Class	Description	Seedlings Affected
		(%)
0	No damage	80
1	Damage with little or no growth loss expected	7
2	Damage with significant growth loss expected	7
3	Expected mortality	6

Herbicide spraying of freshly cut stumps was effective in preventing sprouting on most species (Table 3), with the exception of species in the red oak group. Stumps of hickory, sourwood, dogwood, and yellow poplar were completely killed by spraying with 2,4,5-T, and had no living sprouts. Stumps of red oak species were more difficult to kill and averaged 3.4 sprouts/stump after five years. Sprouting by all species was much greater from cut stumps on unsprayed plots, with dogwood and sourwood producing the greatest quantity. Black cherry and yellow poplar stump sprouts were the tallest and averaged 550 and 480 cm, respectively, after five growing seasons.

Table 3. Effects of herbicide spraying on stump sprouting five years following treatment.

Herbicide Treatment	Species	Number of Sprouts/Stump	Mean Tallest Sprout (cm)
Sprayed	White oak (composite)	0.6	185
	Red oak (composite)	3.4	105
	Hickory	0.0	-
	Sourwood	0.0	-
	Dogwood	0.0	-
	Yellow poplar	0.0	-
Unsprayed	White oak (composite)	3.6	225
	Red oak (composite)	4.8	230
	Hickory	4.0	164
	Sourwood	8.6	256
	Dogwood	17.0	230
	Yellow poplar	6.0	482
	Black cherry	1.0	550
	Blackgum	2.0	300

While herbicide spraying effectively controlled stump sprouting, regeneration of many species from seed stored in the duff and from seedling sprouts provided competition to planted white pine seedlings. Competition was especially intense in the clearcut areas where the number of stems averaged about 19,000/ha versus about 13,000/ha in the residual overstory plots (Table 4). The residual overstory was effective in reducing height of the competition, as well as numbers of competing plants.

The number of oak stems was much greater on both sprayed and unsprayed plots in the residual overstory after five years than in clearcut plots (Table 4). Yellow poplar, dogwood, black cherry, and sweetgum occurred much less frequently in the residual overstory than in the clearcut.

Table 4. Density and height of competing woody vegetation (less than 10 cm diameter at groundline) five years after treatment.

Species	TREATMENT							
	Clearcut sprayed		Clearcut unsprayed		Residual overstory sprayed		Residual overstory unsprayed	
	stems per ha	Ht. (cm)	stems per ha	Ht. (cm)	stems per ha	Ht. (cm)	stems per ha	Ht. (cm)
Oaks	1729	117	2865	119	6150	34	5656	42
Yellow poplar	3754	126	4570	143	1013	57	618	59
Shortleaf pine	3606	128	1828	98	2742	65	716	49
Dogwood	2766	138	3927	185	1359	68	1531	142
Black cherry	1507	144	1902	165	790	52	642	62
Blackgum	1136	147	1210	189	593	89	1309	115
Sweetgum	25	170	568	187	0	0	0	0
Miscellaneous	2989	-	3557	-	2124	-	1507	-
TOTAL	17,512		20,427		14,771		10,979	

Growth of residual overstory trees over the five-year study period was generally much greater than that of similar-sized trees in an adjacent uncut area of the same stand (Table 5). Basal area response on residual overstory trees ranged from 8 to 13 percent while that of corresponding species in the uncut portion of the stand was 2 to 6 percent. Most of the measured trees ranged in age from 60 to 100 years old.

Table 5. Growth of residual overstory trees and trees in an adjacent uncut portion of the same stand over the 5-year study period.

Species	Residual Overstory			Uncut Stand		
	Diameter*		Basal Area Increment	Diameter		Basal Area Increment
	1973	1977		1973	1977	
	-cm-		(%)	-cm-		(%)
White oak	33	36	9	37	39	5
Chestnut oak	30	33	13	35	37	6
Southern red oak	35	38	9	39	40	3
Scarlet oak	36	39	8	28	29	4
Black oak	28	31	11	45	46	2

* Measured at 0.3 meters above ground.

The increased rate of growth of residual overstory trees was accompanied by an increase in epicormic sprouting (Table 6). Each of the five species of oak in the residual overstory plots showed an increase in the number of epicormic sprouts on the first log over the five-year period of the study.

White oak, chestnut oak, and southern red oak had over nine epicormic sprouts on the first log at the end of the study. Three oak species showed no epicormic sprouts on the first log in the uncut area.

Table 6. Epicormic sprout response five years after cutting to a residual basal area of 8 m^2/ha.

	Uncut		Residual Overstory	
Species	1973	1977	1973	1977
White oak	2.5	5.4	4.4	9.0
Chestnut oak	2.0	3.0	6.0	14.0
Southern red oak	0	0	1.3	12.0
Scarlet oak	0	0	0	1.5
Black oak	0	0	0.3	4.7

DISCUSSION

After five growing seasons, planted white pine seedlings were about 30 percent taller in unsprayed clearcut plots than in similar plots with a residual overstory. Controlling stump sprouting with herbicide produced significantly greater height and diameter growth in the clearcut areas. However, the use of herbicide in the residual overstory plots had no effect on either height or diameter growth of white pine seedlings because the lower light intensity reduced both quantity and heights of competing woody vegetation. Herbicide spraying of stumps was especially effective in reducing the number of tall woody sprouts. After two growing seasons, there were more than twice as many tall woody sprouts (over 1.5 m tall) in the unsprayed clearcut plots as in the sprayed clearcut plots (Freeman and Van Lear, 1977). Apparently both overstory and understory competition for light, moisture, and nutrients influence growth of white pine seedlings in South Carolina.

Both sprayed and unsprayed plots in the residual overstory plots contained large numbers of stems of advance regeneration of oak. These stems represent primarily seedlings and seedling sprouts that became established after the mature stand was cut to 8 m^2/ha of basal area. On these plots there were more than 5600 oak stems/ha after five growing seasons. Two factors probably account for the increase in oak reproduction on residual overstory plots. First, seed production can be stimulated by increases in light, moisture, and nutrients following partial cutting. Secondly, the shade furnished by the residual overstory trees inhibits development of intolerant species, thereby reducing competition near the forest floor and allowing the more tolerant oak regeneration to become established. Because both white pine and oak seedlings and saplings are relatively tolerant of shade, they should be compatible and develop into a good quality mixed hardwood-pine stand.

Removal of the overstory trees damaged about 20 percent of the planted white pine seedlings. However, only 6 percent of the seedlings were killed outright or are expected to die by logging activity. No special instructions were given to the loggers except to ask them to take care in locating skid roads and in felling the overstory trees. If initial survival had been

higher, more seedlings would have been damaged, but the percentages should have remained about the same. Thus, it is evident that the overstory can be removed without intolerable damage to the underplanted pine.

A major advantage of underplanting versus clearcutting is the fact that, as the seedlings become established, the residual overstory trees are adding high-value growth. This study shows that dominant and codominant oak trees ranging in age from 60 to 100 years are capable of responding to release. Basal area growth rates of residual overstory trees were more than double those of similar trees in an uncut portion of the same stand. However, an increase in epicormic sprouting on released trees was observed, and may cancel some of the benefit of the increased growth rates.

Several points need to be mentioned concerning the aesthetics of the two alternatives for regenerating white pine. Immediately following clearcutting and the heavy cutting to a residual basal area of 8 m^2/ha, both areas are aesthetically unattractive. Tops of large hardwood trees dominated both areas. After several growing seasons, however, most laymen would probably find the residual overstory plots more appealing than the clearcut plots. A canopy of large, well-spaced trees dominated the residual overstory plots with a relatively sparse understory component of woody regeneration. Logging slash was rapidly disappearing. In the meantime, the clearcut areas were healing over also, but they more closely resembled a jungle of herbaceous and woody vegetation, especially briers. Nevertheless, the clearcut areas were recovering rapidly from the logging operation. After five growing seasons, nearly all logging slash was concealed on the clearcut areas, and a new stand of yellow poplar, shortleaf pine, oak, and white pine was rapidly developing, However, in the shelterwood areas, removal of the residual overstory trees after the fifth season created another scene of logging disturbance that would require another few years to heal. Aesthetically, it was now the least attractive of the two areas. Thus, in discussing the aesthetics of the two methods, one must consider stand development at several points in time.

In summary, both clearcutting and planting and cutting to a residual basal area followed by underplanting appear to be viable alternatives for regenerating white pine in South Carolina. Both methods have advantages and disadvantages. Clearcutting insures faster growth of planted white pine seedlings. It also encourages more rapid development of competition, especially from intolerant species. Clearcutting also does not require reentry into the stand by logging equipment until an improvement cut or thinning is required. Cutting to a residual basal area and underplanting does not allow as rapid growth of white pine seedlings, but does provide additional time for good quality overstory trees to put on high value growth. It also reduces competition from intolerant species and allows a larger component of oak to become established. From a wildlife standpoint, the mast from overstory trees would tend to compensate for the lower production of browse in the residual overstory plots. In addition, the fresh flush of growth following overstory removal would be beneficial to browsing wildlife species, such as deer.

The choice of the appropriate silvicultural practices to regenerate white pine will depend on the owner's objectives as well as silvical characteristics of the species. This study provides information to help the landowner make this choice.

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RESULTS OF THINNING IN A 27-YEAR OLD EASTERN WHITE PINE PLANTATION ON THE SOUTHERN CUMBERLAND PLATEAU OF TENNESSEE

Henry W. Smith, Jr. and Charles O. Baird[1/]

Abstract.--Thinning twice at 11 year intervals in a 27-year old eastern white pine (Pinus strobus L.) plantation near Sewanee, Tennessee, increased board foot growth 150 percent but did not increase cubic foot growth compared to an unthinned plot. A 110 percent increase in board foot growth, but a decrease of 81 percent in cubic foot growth resulted from thinning three times at 7-year intervals. A MAI of 800 board feet per acre may be anticipated with thinning on average sites on the southern Cumberland Plateau of Tennessee. Data are unreplicated.

This paper reports our experience with a stand of planted eastern white pine (Pinus strobus L.) on the southern Cumberland Plateau, Franklin County, Tennessee, at an elevation of 1900 feet. To our knowledge, there is no published growth and yield data available for this species and locality covering such a long period. We emphasize at the outset that our data are unreplicated and therefore only suggest expectations for growth and yield.

Approximately one acre of white pine was hand planted at a 6 x 6-foot spacing on The University of the South's Forest in the spring of 1952, using western North Carolina 2-0 stock. The site chosen for a species comparison demonstration was a 3 1/2-acre field abandoned in 1948 (Anon. 1953, p 29). The predominant soil is Hartsells fine sandy loam, eroded, rolling and undulating phase, and associated soils. (Fox, et al., 1958). Corn and soybeans were probably the principal crops on this 25-acre subsistance farm, and there is evidence of hogs. A prescribed burn just before planting reduced secondary hardwood competition and facilitated planting the heavy stand of broomsedge (Andropogon virginicus L.).

Six 1/9-acre rectangular plots were established when the plantation was 10 years old, their unusual size being dictated by the dimensions of the white pine planting. After the prescribed burn no control of hardwood sprouts and invading seedlings was carried out until the plantation was 25 years old. Lack of hardwood control resulted in understocking and a loss of growth on about half the area as evidenced by a comparison made after 11 growing seasons:

1/ Professors of Forestry, The University of the South, Sewanee, Tennessee. The authors acknowledge Glendon W. Smalley's review of the manuscript, and the many hours of fieldwork their students have contributed.

Stand Condition (11 years old)	No. Trees per Acre	Average DBH, In.	BA/A Sq. Ft.
"Poor" Plots #4,5,6, Hardwood control needed	756	2.5	24
"Good" Plots #1,2,3 Hardwood control unnecessary	876	4.0	81

Although about 900 black locust (Robinia pseudoacacia L.) posts per acre were removed from the "Poor" plots in an improvement cut, early mortality and suppression of growing stock caused an annual growth loss of about 185 board feet as compared with growth on the unthinned "Good" plot.

Stand Condition (27 years old)	No. Trees per Acre	Average DBH, In.	BA/A Sq. Ft.	Cu. Ft. per Acre (3" top)	Bd. Ft. Per Acre (Int.¼")
"Poor" Plots #4,5,6 Hardwood control delayed	402	7.3	113	2,650	9,800
"Good" Plot #3 Unthinned	495	8.4	190	4,600	14,700
"Good" Plots #1 & 2 Thinned	152	12.1	124	4,160[1/]	19,500[1/]

Two of the three "Good" plots, as described in the tables above, were subjected to different thinning regimes between the ages of 11 and 27 years; the third was left unthinned for control.

Tables 1 and 2 and Figure 1 summarize relevant tree and stand parameters on the three plots between the ages of 11 and 27 years. All data shown were derived from the 1/9-acre plots and expanded to an acre-basis.

[1/] Including thinnings.

Table 1.--Thinning summary for a 27-year old white pine plantation at Sewanee, Tennessee

VARIABLE	PLOT NO. 1	PLOT NO. 2	PLOT NO. 3
First Thinning:	AGE 11	AGE 11	
Basal Area Before	78	81	
Basal Area After	48	50	
Cubic Feet Removed	330	230	
Board Feet Removed	-	-	
Second Thinning:	AGE 18	AGE 22	Unthinned
Basal Area Before	120	156	
Basal Area After	93	128	
Cubic Feet Removed	430	90	
Board Feet Removed	-	2300	
Third Thinning:	AGE 25		
Basal Area Before	140		
Basal Area After	85		
Cubic Feet Removed	170		
Board Feet Removed	3800		
Fall - 1978: 27 Years After Planting			
Number of Trees	117	198	495
Basal Area, Square Feet	95	153	190
DBH of Tree Of Mean Basal Area, Inches	12.1	11.9	8.4
No. of Trees ≧ 10" DBH	117	153	125
Average Total Height of Dominants and Codominants, Ft.	68	66	72
Indicated Site Index, 25-year Base Age. (Vimmerstedt, 1962)	60	60	65
Cubic-Foot Volume to 3" Top Diam.	2,800	4,300	4,600
Board-Foot Volume (Int. ¼" Rule) Trees ≧ 7" DBH to 6" Top Diam.	12,300	19,700	14,700
TOTAL PRODUCTION)(CUBIC FEET	3,730	4,600	4,600
INCLUDING THINNING)(BOARD FEET	16,100	22,000	14,700

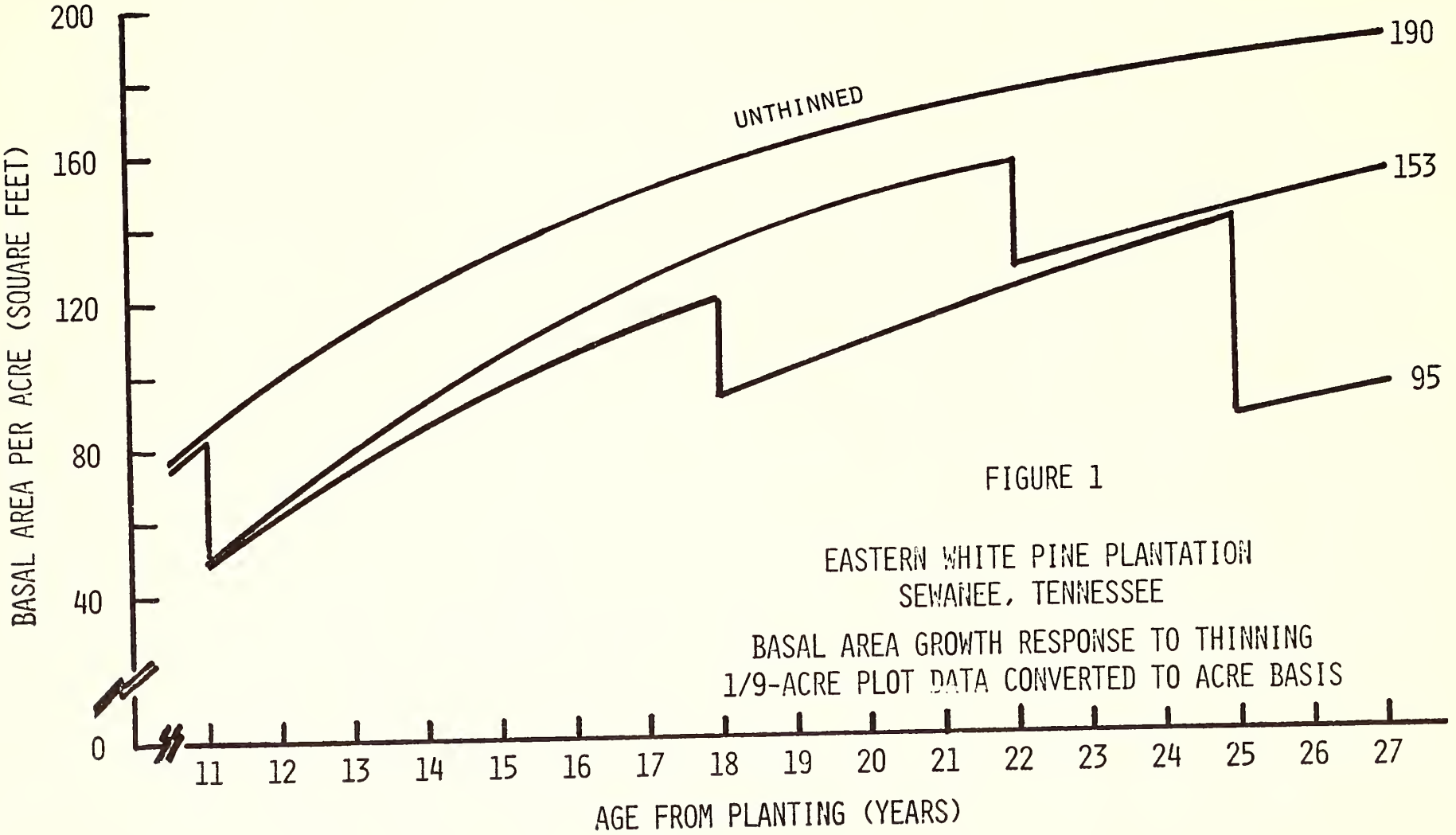

FIGURE 1

EASTERN WHITE PINE PLANTATION
SEWANEE, TENNESSEE

BASAL AREA GROWTH RESPONSE TO THINNING
1/9-ACRE PLOT DATA CONVERTED TO ACRE BASIS

Table 2.--Diameter distribution 27 years after planting

DBH Class	Number of Trees Per Acre		
	Plot 1 Thinned Three Times	Plot 2 Thinned Twice	Plot 3 Unthinned
4			27
5			45
6			81
7		9	72
8		9	90
9		18	27
10	27	27	90
11	27	18	45
12	0	45	0
13	36	18	18
14	18	45	
15	9	9	
Total	117	198	495

RESULTS OF THINNING

Plot 1, thinned three times at ages 11, 18, and 25 has a present volume of 12,300 board feet per acre plus 3,800 board feet removed in the last thinning. Although the mean stand diameter of 12.3 inches is nearly 4 inches larger than the unthinned stand, fewer stems give a basal area of only 95 square feet compared to 190 square feet for the unthinned stand (Figure 1). Board foot volume on Plot 1 plus thinnings exceed that of the unthinned stand by 1,400 board feet, but present cubic volume plus thinnings fall 870 cubic feet short of the unthinned white pine (Table 1). The presence of F. annosus, storm losses, and heavy thinning at age 25 lowered productivity on this plot.

Plot 2, thinned at ages 11 and 25, has a present volume of 19,700 board feet. Adding 2,300 board feet removed five years earlier gives a total production of 22,000 board feet per acre. There are 162 stems 10 inches and larger (Table 2), and basal area has increased at an annual rate of 4 square feet for a present stocking of 153 square feet (Figure 1 and Table 1). On this plot live crown ratios are adequate; crop trees are well spaced; annual radial growth is about 0.25 inch; and mean annual increment including thinnings exceeds 800 board feet. One may predict such a yield from unthinned white pine plantations on SI_{25} 65, but at an initial spacing of 7 x 7 feet and for total age from seed of 30 years (Vimmerstedt 1962, p 13).

After 27 years, competition in the unthinned stand (Plot 3) has reduced the number of stems by about 40 percent. This stand averages 8.4 inches DBH and contains 14,700 board feet per acre (4,600 cubic feet) (Table 1). There

are 153 stems 10 inches and larger (Table 2), and basal area has been increasing in the last five years at the annual rate of about 1 square foot to a present stocking of 190 square feet (Figure 1). This unthinned plot falls some 3,000 board feet short of the yield table volume of about 18,000 board feet (Vimmerstedt 1962, p 13), although the mean DBH of the stand is about 1 inch larger than Vimmerstedt's value for comparable site, age, and original spacing.

MANAGEMENT HISTORY

In the fall of 1965 all trees on the "Good" plots were pruned to head height to improve stand accessability. After the 11th growing season about 110 potential crop trees per acre were selected and pruned to the base of the live crown. Lammas growth has not been a problem.

To accelerate, or at least maintain radial growth, a precommercial crown thinning was also carried out after the 11th growing season. An average of 4 cords (280 cubic feet) per acre were removed from Plots 1 and 2, and the number of stems and basal area were reduced nearly 40 percent (Figure 1 and Table 1). Stumps were painted liberally with creosote in this and all subsequent thinnings to forestall Fomes annosus (Fr.) Cke. infection.

When the plantation was 18 years old, a second precommercial crown thinning on Plot 1 removed about 6 cords per acre (430 cubic feet), and reduced basal area from 120 to 93 square feet (Figure 1 and Table 1). The residual stand had a DBH of 6.6 inches with potential crop trees averaging 2 inches larger.

Plot 2, which had been slightly damaged by a December, 1972 ice storm, was thinned for a second time at age 22. Fomes annosus was present and probably contributed to storm damage as this was the only plot affected. Between thinnings, basal area increased at the rate of nearly 10 square feet per year. After thinning, mean DBH was 9.0 inches and crop trees averaged 11.5 inches (Figure 1 and Table 1).

Plot 1 was thinned again at 25 years. The remaining crop trees were pruned to a height of 25 or 33 feet depending on tree size and condition. Basal area was reduced from 140 square feet to 85. Unlike the previous thinnings at ages 11 and 18, this cut combined crown thinning with thinning from below. Trees in intermediate crown classes left by the earlier crown thinnings were cut for small sawlogs. This approach to thinning resulted in a heavier cut than otherwise would have been made, and can best be described as "free thinning" (Smith 1962, p 89). Three thousand eight hundred board feet per acre in small sawlogs, and 170 cubic feet in tops were removed (Figure 1 and Table 1). A 7-year thinning interval had been employed on Plot 1, but to continue at this frequency would be unwise, as indicated by present stand parameters. Five years' basal area growth will add about 25 square feet for a projected stocking of 120 square feet per acre. This would be less than current stocking on Plot 2 which had been thinned twice at an 11-year interval.

In the last 10 years white pine seedlings have gradually become established on the southern border of Plot 1 under an overstory of shortleaf pine (Pinus echinata Mill.) planted at the same time as the white pine. As many as 14,000 seedlings per acre persist in the shortleaf understory. We attribute this to more favorable light and suitable seedbed caused by mortality, high sparse crowns, and the invasion of black locust and yellow-poplar (Liriodendron tulipifera L.).

The third thinning on Plot 1 inadvertently stimulated regeneration beneath the white pine canopy where densities of 45,000 1- and 2-year old seedlings can be found.

Comparative Performance of a Nearby Younger Plantation

Another nearby white pine plantation established 15 years ago on similar soil and site with a 6 x 6-foot spacing was thinned and pruned in 1977 (Table 3). What has amounted to free thinning has left 250 stems per acre and reduced basal area from about 125 to 93 square feet per acre. The present stand of 7,100 board feet, has grown at a MAI of 470 board feet per acre per year.

Table 3.--Performance of a 15-year old white pine plantation at Sewanee, Tennessee following a first thinning at age 15

		Diameter Distribution	
Number of Trees	250		
Basal Area, Square Feet	93		
DBH of Tree of Mea		DBH	No. Trees
Basal Area, Inches	8.3	7	50
No. Trees ≧ 10" DBH	20	8	130
Average Total Height of		9	50
Dominants and Codominants, Ft.	41	10	20
Indicated Site Index	62		
Cubic-Foot Volume			
to 3" Top Diam.	2,300		
Board-Foot Volume (Int. ¼" Rule)			
Trees ≧ 7" DBH to 6" Top Diam.	7,100		

CONCLUSIONS

As reported here, eastern white pine appears to have significant commercial potential as a plantation species in the southern portion of the Cumberland Plateau in Tennessee. In this location it is superior in its resistance to ice damage (Burton and Gwinner, 1960). White pine blister rust (Cronartium ribicola Fischer), white-pine weevil (Pissodes strobi Peck), and pales weevil (Hylobius pales Herbst.) are not known to be serious threats in the southern Cumberland Plateau region and F. annosus can be minimized by treating with borax (Anon. 1977).

The exigencies of time and fortune, it would seem, leave only compound interest and fire to contend with to date. But aren't these risks common to any long-term tree crop? And does not a mean annual increment of 800 board feet per acre for intensively managed eastern white pine appear attractive?

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POSSIBILITIES OF PITCH X LOBLOLLY PINE HYBRIDS IN THE INTERIOR SOUTH

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ABSTRACT.--Test plantings made since 1971 in western Kentucky, West Virginia, western Virginia, Maryland, and southern New Jersey suggest that pitch X loblolly pine hybrids offer great promise of providing fast-growing, winter-hardy pines for the interior South. With enough work in selection, breeding, and testing, hybrids can be produced that apparently will rival loblolly pine's rate of growth. They even have such growth on relatively poor sites and in areas where loblolly pine suffers both winter drying and dieback. Much more work needs to be done to obtain such hybrids and then to provide material for mass plantings.

Introduction

Loblolly pine (*Pinus taeda*) is the principal commercial species of pine from central Delaware south to northern Florida and west to Texas and southern Arkansas, but unfortunately it is not native to much of the interior South. Central and western Maryland, more than half of Virginia, portions of the Carolinas and Georgia, much of Tennessee and Arkansas, and all of Missouri, Kentucky, and West Virginia are outside of loblolly's natural range (Fowells, 1965).

Among the minor pines of the South, the most cold-resistant appears to be pitch pine (*P. rigida*). Its range extends from Bar Harbor, Maine, southern Quebec, and southern Ontario to northern Georgia. Although pitch pine grows both inland and along the coast in New England, New York, and New Jersey, southward its range is inland around the mountains (Fowells, 1965). In the Great Smoky Mountains and vicinity, pitch pine occurs at elevations between 1,400 and 4,500 feet (Whittaker, 1956).

Although pitch pine has often been sawed for lumber, cut for piling or pulpwood, or in bygone days tapped for naval stores, its reputation among most foresters is poor. This seems partly due to its occurrence on poor sites, but mostly due to the poor growth and form of trees that either started as sprouts or were deformed by wildfires. Seedlings of pitch pine may develop into well-formed trees and may reach maximum heights of about 100 feet, and such stems are the ones that produce relatively good lumber. However, pitch pine's growth is slower than loblolly's: where the two

species grow together, loblolly pines are taller, often by 10 to 15 feet at 30 to 50 years, and larger in diameter (Little et al., 1967).

Foresters have long been interested in combining pitch pine's winter hardiness with loblolly pine's rate of growth. In 1945 the Northeastern Forest Experiment Station established test plantings of pitch X loblolly pine hybrids that came from controlled pollinations at the Forest Service's Institute of Forest Genetics at Placerville, California. However, these hybrids were similar to pitch pine in growth and form (Little and Somes, 1951; Little et al., 1967). In contrast, some natural hybrids of the two species grew nearly as fast, and with nearly as good form, as loblolly seedlings (Little et al., 1967). Extensive use of pitch X loblolly pine hybrids in Korea (Hyun, 1962) has also stimulated interest in their use in this country.

About 1963 Westvaco personnel became interested in the possibility of developing fast-growing, winter-hardy, yellow pines for company lands in western Virginia, West Virginia, southern Ohio, and western Maryland. Pitch X loblolly pine hybrids were one good possibility, so research foresters of Westvaco and the Northeastern Station agreed to cooperate on the study described in this paper.

Study Procedures

In late 1963 and early 1964 Westvaco and Station personnel--with the help of state foresters and other interested people--started to select apparently superior trees. Selections were based mostly on height and form. Most chosen trees were 3 to 15 feet taller than their associates. Pitch pines selected were relatively old; mostly 65 to 160 years. Loblolly pines were usually younger; many were 30 to 60 years old.

Tree climbers were employed to collect scion material and Westvaco personnel grafted it on seedlings planted in 1963 near Charlottesville, Virginia. In the fall of 1964 Westvaco dug 653 successfully grafted seedlings, wrapped their root systems and soil balls in burlap, and loaded them on vans for shipment to New Lisbon, N. J., where the Station established an orchard. Westvaco did some additional grafting for the New Lisbon orchard in 1965, and since then Station personnel have done some grafting to add a few clones or to replace trees that died.

In the 5-acre New Lisbon orchard there are now 32 clones of pitch pine and 33 of loblolly. Two of the loblolly clones are from southern Delaware, the rest from eastern Maryland. Pitch pine clones are from West Virginia, Virginia, southern New Jersey, northwestern New Jersey and northeastern Pennsylvania, north-central Pennsylvania and south-central New York, northeastern New York, southeastern Massachusetts, New Hampshire, and Maine.

In 1968, 4 years after grafting, controlled pollinations began in the orchard; they extended through 1974. In total, 2,462 pollination bags were used during that period, mostly on pitch pine clones. Practically all of the controlled pollinations were between clones: pollen of one clone, usually loblolly, was applied to bagged flowers of the other species. Before 1972 we had to go back to loblolly ortets for male flowers, because the grafted loblollies were slower and less prolific in flowering than the

pitch pine clones in the New Lisbon orchard. In some years Westvaco shipped loblolly pollen from clones selected in South Carolina or Virginia for use in the New Lisbon orchard.

Although the initial crosses involved few of the selected clones, we decided to start progeny tests as soon as possible. If we had waited to obtain seeds from crosses between most of the selected clones, we might have been involved with 800 to 1,000 crosses, and trials of that many stocks are not feasible for us. In the progeny trials we have used row plots (usually, but not always, 10 trees per row plot) and three or six blocks in a planting. Seedlings have been grown to 1-0 stock in a state nursery, most of them by the Maryland Forest Service.

Between 1971 and 1977, 29 test plantings were established in nine states. These included two small plantings in western Kentucky, six plantings in West Virginia, three in western Virginia, four in Maryland, three in central Pennsylvania, three in southern New Jersey, two in northern New Jersey, two in Saratoga County, New York, two in Massachusetts, and two in south-central New Hampshire. The number of hybrid stocks in a planting ranges from 11 to 103, and the number of check stocks from 2 to 9. Twenty of the plantings have between 30 and 59 hybrid stocks. (For more details see Little and Trew, 1976, 1977.).

Planting sites differ greatly in elevation, climate, soil, and past land use. The 1972 West Virginia planting is at 3,250 feet; the 1973 site in southern New Jersey at about 140 feet. The length of the growing season differs by about 90 days: from about 195 days in western Kentucky to only 100 or 110 days at the 1972 site in West Virginia. Minimum temperatures may differ by 23°F. Soils differ greatly, too. The 1971 West Virginia site has shallow soil, only 14 to 18 inches deep; the southern New Jersey sites have deep Coastal Plain sands. Some of the sites were old fields; others had been wooded and were prepared by cutting, bulldozing, or drumming. Only one site, that in Garrett County, Maryland, was in a strip-mined area.

Study Results

Not all the plantings have been highly successful. Survival and growth of trees in certain plantings have been adversely affected by excessive competition from grass, by excessive deer browsing, rabbit clipping of stems, girdling by meadow mice, complete defoliation by red-headed pine sawflies, or damage by other insects or by vandals. Survival and growth have been good in some plantings: for example, the lowest 1977 survival of hybrid stocks in the 1971 West Virginia planting was 67 percent, and in 22 of the 32 crosses the survival was 85 to 100 percent.

Some of the hybrid stocks tend to be taller than regular loblolly pines as 1-0 stock, and height differences between the best hybrids and pitch pine checks tend to increase with time. In the 1974 planting in southern New Jersey, the average height of the tallest hybrid just after planting was 0.85 foot, that of Maryland loblolly was 0.65 foot, and of seed-orchard pitch pine from wind pollination 0.46 foot. Four growing seasons later the average height of the tallest cross was 7.68 feet, and comparable values

Table 1.--Average (and maximum) heights of best three hybrids and of certain check stocks in some of the plantings at the end of the 1977 growing season

Planting	Hybrids			Seed-orchard pitch pine	Maryland loblolly pine	Korean pitch X loblolly pine
	Cross	Geographic sources	Average (and maximum) heights			
			Feet	Feet	Feet	Feet
1971 Livingston County, Ky.	72 X 15A	Mass. X Md.	18.9 (22)	13.5(16)	19.7(22)	14.9(18)
	70 X 15A	Pa. X Md.	18.4 (22)			
	78 X 15A	Maine X Md.	17.9 (20)			
1972 Livingston County, Ky.	62 X 7-56	N.Y. X S.C.	15.5 (18)	10.6(14)	15.5(19)	--
	62 X 11-9	N.Y. X S.C.	15.1 (18)			
	62 X 11-20	N.Y. X S.C.	14.9 (18)			
1971 Monroe County, W. Va.	70 X 15A	Pa. X Md.	16.9 (18.6)	10.9(13.3)	14.9(17.3)	13.3(16.2)
	66 X 15A	N.J. X Md.	16.6 (18.9)			
	77 X 23	N.H. X Md.	16.6 (18.4)			
1973 Ritchie County, W. Va.	62 X 11-20	N.Y. X S.C.	7.6 (11.0)	4.4(6.9)	5.9(9.2)	5.5(8.5)
	65 X 15A	N.J. X Md.	7.5 (11.0)			
	54 X 7-56	Va. X S.C.	7.5 (11.2)			
1975 Patrick County, Va.	59 X 7-56	Pa. X S.C.	5.0 (7.0)	2.3(3.3)[1/]	4.2(6.2)[1/]	3.0(4.3)
	59 X 11-10	Pa. X S.C.	4.6 (7.0)			
	81 X 7-56	N.Y. X S.C.	4.6 (6.8)			
1972 Cecil County, Md.	62 X 11-10	N.Y. X S.C.	11.9 (14.7)	6.6(9.8)	10.8(14.5)	--
	62 X 11-9	N.Y. X S.C.	11.7 (14.5)			
	62 X 7-56	N.Y. X S.C.	11.7 (15.2)			
1973 Cecil County, Md.	54 X 7-56	Va. X S.C.	11.2 (15.5)	6.4(12.4)[2/]	10.4(16.3)	7.3(10.6)
	76 X 22	N.H. X Md.	10.8 (14.1)			
	62 X 7-56	N.Y. X S.C.	10.8 (15.2)			
1973 Ocean County, N.J.	65 X 23	N.J. X Md.	8.5 (10.9)	6.3(7.9)	8.4(11.8)	6.1(9.5)
	62 X 7-56	N.Y. X S.C.	8.5 (11.8)			
	78 X 15A	Maine X Md.	8.2 (11.0)			
1974 Ocean County, N.J.	24 X 72	Md. X Mass.	7.7 (10.6)	5.2(8.3)	4.9(7.9)	5.0(7.4)
	67 X 22	N.J. X Md.	7.3 (9.9)			
	75 X 22	N.H. X Md.	7.3 (10.9)			

[1/] Not seed-orchard pitch pine nor Maryland loblolly, but from seeds supplied by the Virginia Division of Forestry.

[2/] Tallest tree is apparently a natural hybrid between pitch and loblolly pines.

for loblolly and pitch checks were 4.86 and 5.25 feet. Thus in 4 years the difference between the best hybrid and the pitch check had increased from 0.4 to 2.4 feet. However, as data in other papers (Little and Trew, 1976, 1977) show, some hybrids have growth similar to the pitch pine checks.

In that New Jersey planting, loblolly pine has been growing poorly, apparently because the soil is a droughty, relatively coarse sand--the type of site to which the hybrids seem better adapted because of their very extensive, very fibrous root systems. In certain crosses the roots of 1-0 seedlings approach 2 feet in length before they are pruned for planting. Similar root systems of the hybrids were also noted in the 1945 test planting (Little and Somes, 1951), and these greatly exceed the root systems of both parents, but especially loblolly, in length and branchiness. In the 1974 New Jersey planting where loblolly pine was struggling, the three best hybrids at 4 years had average heights of 7.3 to 7.7 feet, or exceeded at the same age the average heights (6.4 to 6.7 feet) of the three tallest hybrid stocks in the nearby 1973 planting on Evesboro soil. As Table 1 shows, regular loblolly pine grows fairly well on Evesboro soil, having an average height of 8.4 feet in 1977, just about the same as the 8.5 of the two best hybrids in that planting.

Particularly outside of its natural range, loblolly pine suffers winter damage--first winter drying of its foliage, and in the colder sections dieback and death of some stems. For example, under the milder winters of Cecil County, Maryland, the 1977 survival of Maryland loblolly in a 1972 planting was 93 percent; however, in the West Virginia planting of the same year but at 3,250 feet it was only 32 percent. In contrast, the survival of the tallest three hybrids in those plantings was 93 to 100 percent in Maryland, 95 to 98 percent in West Virginia. The hybrids, particularly between northern pitch pines and Maryland loblolly, are showing much greater resistance to such winter damage and to damage from wet snows and ice than loblolly pines of Maryland source. And in one study loblollies of that source were more resistant to damage by wet snows than trees of eight more southern sources (Little and Tepper, 1959).

In most of the plantings where loblolly pine tries to thrive, the best hybrids match or exceed the growth of regular Maryland loblolly (Table 1). That is true of the 1972 Kentucky planting and the plantings in Cecil County, Maryland, but not quite true of the 1971 Kentucky planting. Results from the last might have been different if it had included 40 hybrid stocks rather than the 11 actually used. On less favorable sites for loblolly, such as the 1971 West Virginia planting at 2,350 feet or the 1973 one near the Ohio River, the best hybrids are exceeding regular Maryland loblolly in height growth.

In most of our test plantings, Korean pitch X loblolly pine hybrids have been used as one of the check stocks. Usually these have grown about as fast as some of the pitch pine check stocks and not nearly so fast as the best of our clonal crosses (Table 1). Presumably the Korean trees of our plantings are F_2 hybrids from wind pollinations of F_1 hybrids, but Hyun (1974) reports that his F_2 hybrids are equal to his F_1 hybrids. A possible reason for the difference between Korean hybrids and our best crosses may be more careful selection of parent trees and the use of full-sib progeny tests for selection

of the best crosses, or perhaps there has been some backcrossing with nearby pitch pines for the Korean seed we used.

Supplying Materials for Mass Plantings

Because the best hybrids grew so rapidly and were winter hardy, practicing foresters started to ask for materials for mass plantings in 1975, about 4 years after the first test plantings were established. To date, requests have come in from several states. We have no material for mass plantings, but steps have been taken to provide a supply.

We do not know just what procedures should be used, but there are at least four possibilities. These are (1) wind pollination in 2-clone orchards, one of each species, as Hyun (1976) and others have mentioned; (2) mistblowing pollen of selected clones of one species on selected clones of the other species; (3) wind pollination in F_1 orchards, based on the best trees in the best crosses of local plantings as scion sources; and (4) vegetative propagation of the best trees within the best crosses. The 2-clone orchards do not seem too feasible even in places like southern New Jersey where both species could be grown, because there would be many years when flowering of the two clones would not coincide. In those years pollen could be applied by mistblower. However, a large number of orchards, possibly 30, should be created to provide genetic diversity in the forest plantings. Mistblowing pollen of selected loblolly clones on selected pitch clones has been tried at New Lisbon for 3 years, following procedures suggested by Dr. E. C. Franklin of the Southeastern Forest Experiment Station and others. Because of contaminating pollen sources inside and outside of the orchard, that procedure seems limited in value in the New Lisbon and similar orchards. Even in orchards with only one clone of each species, mistblowing pollen requires enough work in gathering flowers and extracting and applying pollen to make that procedure seem less feasible than the next possibility.

This is using F_1 orchards, as Hyun (1976) is doing in Korea. Because we don't know the value of such orchards, the Maryland Forest Service and New Jersey Bureau of Forestry grafted this past spring for small F_1 orchards, using as scion sources the best trees in 16 or 17 of the best crosses within plantings of the respective states. The fourth possibility, vegetative propagation, might follow techniques developed by Hare (1974); its feasibility should also be investigated.

Future Work

Much more work needs to be done in selecting suitable parent trees, making controlled crosses and test plantings, and providing suitable measures for supplying high-quality materials for mass plantings. Westvaco has established a 3-acre orchard of grafted pitch pines, 30 selected clones, in its Summerville, S. C., seed-orchard complex. It will make and test additional controlled crosses between the two species. The Hiwassee Land Company is starting a similar orchard in Tennessee for the same purpose. The Northeastern Forest Experiment Station plans on expanding its New Lisbon orchard and making additional controlled crosses for test plantings. Some of the Station's plantings and probably all of the two companies' plantings will be

in the interior South: i.e., south of the Mason-Dixon line and Ohio River and outside of loblolly pine's natural range.

If these controlled crosses are to be the best ones for different areas, we will have to take advantage of the genetic variation within both species--both in growth and in adaptation to different climates. For example, recent information (Little, 1978) indicates that within pitch pine there are slow-growing strains, and seedlings of such a strain even when undamaged by fire will reach at 50 years only about half the height of trees of certain other strains grown on the same site. Loblolly and probably pitch pines from southern sources are faster-growing than those from northern sources, but not so winter-hardy. However, there are indications that hybrids may have about as much winter-hardiness as the pitch pine parent if it is crossed with Maryland loblolly. If this is true, the best crosses for the Cumberland Plateau of Tennessee may be between a Virginia, Tennessee or North Carolina pitch pine and a loblolly pine from South Carolina, Georgia, or Mississippi, and crosses between a northern pitch pine and a Maryland or even South Carolina loblolly would not grow so rapidly. On the other hand, for relatively high elevations, such as 3,250 feet in West Virginia, crosses between northern pitch pines and Maryland loblolly are proving to be the best, as they are in upstate New York and central New England.

Possible Role of the Hybrids in the South

From our test plantings we conclude that pitch X loblolly pine hybrids offer great promise of providing rapid-growing, winter-hardy pines for the interior South. With enough care in selection and enough effort in breeding and testing, hybrids can apparently be produced that will grow about as rapidly as regular loblolly pines and still be winter-hardy. The hybrids will also have good growth on some droughty soils where loblolly does not thrive. The pitch X loblolly pine hybrids offer great promise of good to excellent growth on soils where the site index for hardwoods is low to mediocre.

In some sections of the South within loblolly pine's natural range, certain pitch X loblolly pine hybrids may be valuable in reducing losses to fusiform rust. In recent tests the Fusiform Rust Resistance Screening Center found that among seedlings from three seed lots of our hybrids, the infection rate was about half that among seedlings from their loblolly parents.

Acknowledgment

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EFFECTS OF SITE AND INHERITANCE ON FUSARIUM INCIDENCE IN VIRGINIA PINE

Paul E. Barnett[1] and Eyvind Thor[2]

ABSTRACT. Height growth of Virginia pine was reduced and susceptibility to pitch canker increased on a more poorly drained site. Performance of progenies from 22 controlled crosses indicates that height growth is inherited in an additive manner while resistance to pitch canker appears to be controlled by dominance or epistatic gene action.

In the Spring of 1973 TVA's Division of Forestry, Fisheries, and Wildlife Development established a Virginia pine (Pinus virginiana Mill.) progeny test near South Holston Dam in Sullivan County, Tennessee. During the course of routine height measurement in 1976, it was noted that a significant number of seedlings had broken over at a point 6 to 18 inches above the soil surface. Subsequently, pathologists at the Department of Pathology and Entomology, The University of Tennessee Agricultural Experiment Station, Knoxville, Tennessee, diagnosed the cause to be pitch canker, induced by the fungus Fusarium lateritium f. pini Hept.

Pitch canker was discovered during the early spring of 1945 near Asheville, North Carolina, when dead branches and leaders were noted in a Virginia pine stand (Hepting and Roth 1946). Because of excessive pitch flow and the accumulation of pitch below the canker, the disease is difficult to confuse with other canker diseases. The fungus has been isolated from cankers on shortleaf, slash, longleaf, Scotch, pitch, and Table-Mountain, in addition to Virginia pine (Berry and Hepting 1959).

Evidence suggests that the pathogen is carried by insects such as tip moths, weevils, or sawflies, which feed on pines (Berry and Hepting 1959, Matthews 1962). Since the means of spread is not known for certain, control measures have not been developed. Sanitation cutting is not an effective means of control (Bethune and Hepting 1963); there is no relationship between newly diseased trees and location or number of previously diseased trees (Schmidt and Underhill 1974).

Materials and Methods. The planting was established on an area made up of a combination of Sequatchie fine sandy loam (2-5 percent slope) and Staser fine sandy loam (0-3 percent slope) along the South Holston River (USDA, SCS 1944). Progenies from 22 controlled crosses performed in TVA's Virginia pine seed orchard were planted in five-tree family row plots using a randomized complete block design replicated 10 times. Spacing was 8 feet by 8 feet. Infected trees were tallied each spring for three years (1976 through 1978), hoping that some parents or crosses might exhibit resistance to the disease. No attempt was made to segregate stem- from limb-cankered trees.

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Percentage infection (incidence) data were transformed by the arc sin $\sqrt{\text{percent}}$ transformation prior to analysis of data by the analysis of variance.

Results. Results of the analysis of height data and Fusarium incidence are presented in Table 1. Variation due to replication effect was highly significant for both disease incidence and height. This observation led to further investigation of the site on which the material is growing. Casual observation had revealed that one side of the site appeared less well-drained than the remainder

Table 1. Analysis of variance - Fusarium incidence and total height for progenies from seven Virginia pine clones in a six-year-old planting in east Tennessee.

N	Source of Variation	df	Fusarium Incidence MS	Fusarium Incidence F	Total Height MS	Total Height F
10	Replication	9	1586.9	5.91*	18.94	12.68*
7	Clone	6	932.6	0.95NS	8.38	4.15*
	Clone x Rep.	54	389.8	1.45NS	1.72	1.15NS
3	Cross w Clone	14	865.6	3.22*	1.79	1.20NS
	Error	126	268.6		1.49	
	Total	209				

* Denotes statistical significance at the 1 percent level of probability.

of the area. Sampling the soil with an Eppley soil tube revealed definite mottling at a depth of six inches on one side of the planting; mottling decreased gradually across the planting. Since both soil types are reportedly well-drained, it is obvious that a part of the area is not accurately mapped.

No significant difference was noted among clones for Fusarium incidence, while for total height among clones variation was highly significant (Table 1). On the other hand, for crosses within clone, there was no significant difference in total height while for Fusarium incidence this source of variation was highly significant. These results indicate that while height growth is inherited in an additive manner, as has been reported on numerous occasions for forest tree species, resistance (or susceptibility) of Virginia pine to pitch canker appears to be transmitted in a specific manner, suggesting dominance or epistatic gene action.

From the variance component analysis (Table 2) it is noted that site variation (replication) contributed over twice as much to variation in total height as to disease incidence. The relative contributions of clones and crosses within clone strongly suggest that height growth is inherited in an additive fashion while Fusarium resistance is governed by dominance and/or epistatic effects.

Table 2. Variance component analysis - Fusarium incidence and total height for progenies from seven Virginia pine clones in a six-year-old planting in east Tennessee.

Source of Variation	Fusarium Incidence		5-year Height	
	Variance	% of Total	Variance	% of Total
Replication	57.0	13.4	0.820	31.2
Clone	0.0	0.0	0.212	8.1
Rep. x Clone (Error 1)	40.4	9.5	0.077	2.9
Cross w/in Clone	59.7	14.1	0.030	1.1
Error (Error II)	268.6	63.4	1.493	56.7
Total	425.7	100.4	2.632	100.0

Conclusions. Analysis of data on disease incidence and growth in this six-year-old Virginia pine progeny test disclosed some factors which could prove significant in future management of this species. Variation due to replications was highly significant in the case of both total height and pitch canker infection. The most likely explanation is poor soil drainage over part of the site; growth of Virginia pine was reduced and susceptibility to pitch canker increased on the more poorly drained site.

The highly significant variance component observed for crosses within clone is of importance to tree breeders. Future breeding and testing of Virginia and other pine species susceptible to pitch canker are needed to determine the extent of specific combining ability for resistance to this disease.

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PERFORMANCE OF WHITE PINE CONTAINERIZED SEEDLINGS IN NORTH CAROLINA

O. C. Goodwin[1/]

Abstract.--Tests indicate that white pine (Pinus strobus L.) containerized seedlings may be used to extend the regular planting season and to immediately replant 2-0 seedling failures during the summer months. Although, the survival and growth of September planted 11 weeks old white pine tubelings was considerably less after 5 growing seasons than that of 2-0 bare root seedlings planted the following spring, older and larger June-planted containerized seedlings are outperforming in growth the fall-planted tubelings after two growing seasons.

Additional keywords: Tree planting, Pinus strobus, height growth.

A study was begun in 1972 by the North Carolina Division of Forest Resources to evaluate tubeling techniques developed in Ontario. The primary objective was to determine if tubelings could be successfully used to extend the planting season through the summer and fall months. Also we wanted to determine if we could improve upon the survival of some problem species. Tests were conducted with white pine (Pinus strobus L.) and Fraser fir (Abies fraseri) in the North Carolina mountains, and with loblolly (Pinus taeda L.), longleaf (Pinus palustris Mill.), and slash pine (Pinus elliottii Engelm.) in the coastal plain. This study has demonstrated that the Canadian techniques with modifications are applicable to these species.

In 1970 and 1971 we were experiencing difficulty in getting good survival of white pine 2-0 and 3-0 seedlings and we thought containerized seedlings might help us overcome this problem. These problems were corrected and we are now getting good survival of 2-0 stock. We have discontinued growing 3-0 stock.

MATERIALS & METHODS

Three successive crops of white pine tubelings were grown during the summer of 1972 in our Piedmont experimental greenhouse located at our former Griffiths Tree Nursery near Clayton (Goodwin 1972). The 3/4 inch diameter and 4-inch long Ontario split, styrene tube was used for all these crops. A pure peat soil containing one ounce of pulverized 10-10-10

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fertilizer (with trace elements), 5 ounces of dolomotic, unburned lime and 2 ounces of weathered pine straw mycorrhizal inoculum was used as the growing medium. No other nutrients were added to the medium. Seed from the same seedlot with a germination test of 75 percent was used for all crops. Fresh stratified seed gave the best germination results of 55 percent. Two seed per tube were used to increase the number of containers with a germinant. When both seed germinated, the extra seedling was pulled from the tube and replanted in containers with a germinant.

All three tubeling crops were grown with the loblolly and longleaf pine crops for 5 to 6 weeks in the greenhouse at temperatures ranging from 70° to 95° F. Watering was done by mist sprayers operated by a time clock so that the growing medium was always moist. Intermittent night lighting of 30 foot candles per square foot was applied for one minute at 10 minute intervals from dark to daylight. The tubelings were moved to unshaded, outdoor benches for 5 to 6 weeks to condition them for planting. When planted, they averaged 6.9 cm to 7.8 cm (2.7 to 3.1 inches) in height and 1.2 mm to 1.4 mm in root collar diameter. (Figure 1).

A fourth crop of tubelings was grown during the winter for 20 weeks in the greenhouse and conditioned on outdoor benches for 6 weeks. These 15 weeks older tubelings were somewhat larger than the three crops of 11 weeks old tubelings. They averaged 11.0 cm (4.3 inches) in height and 1.6 mm in root collar diameter and were 1.7 inches taller and .3 mm larger at the root collar than the younger tubelings.

The Ontario planting hoe-dibble was used to plant these 11 weeks old tubelings on an old pasture on August 10, and on two KG and piled areas on September 25 and November 15.

PLANTING RESULTS

Of these four planting tests of white pine tubelings, only the September 25 test has survived after five growing seasons. Frost heaving of one to four inches for 64 percent of the August planted and 100% for the November-planted tubelings resulted in failures of these two tests. An errant bull kept getting into the old pasture test-planting and eventually devoured all of the tubelings that were not frost heaved. All failures are attributed primarily to the time of planting. Because they were not planted until the end of the growing season, the roots did not egress from the tube bottom and anchor the seedlings in the soil. The freezing and swelling of the soil around the smooth-textured tubes caused them to literally squirt out of the ground. Unfortunately, the fourth crop of the larger tubelings planted on April 24 was accidently destroyed by a grading operation. Therefore, it could not be determined if they would also have experienced the same degree of frost heaving and consequently would have grown at a faster rate.

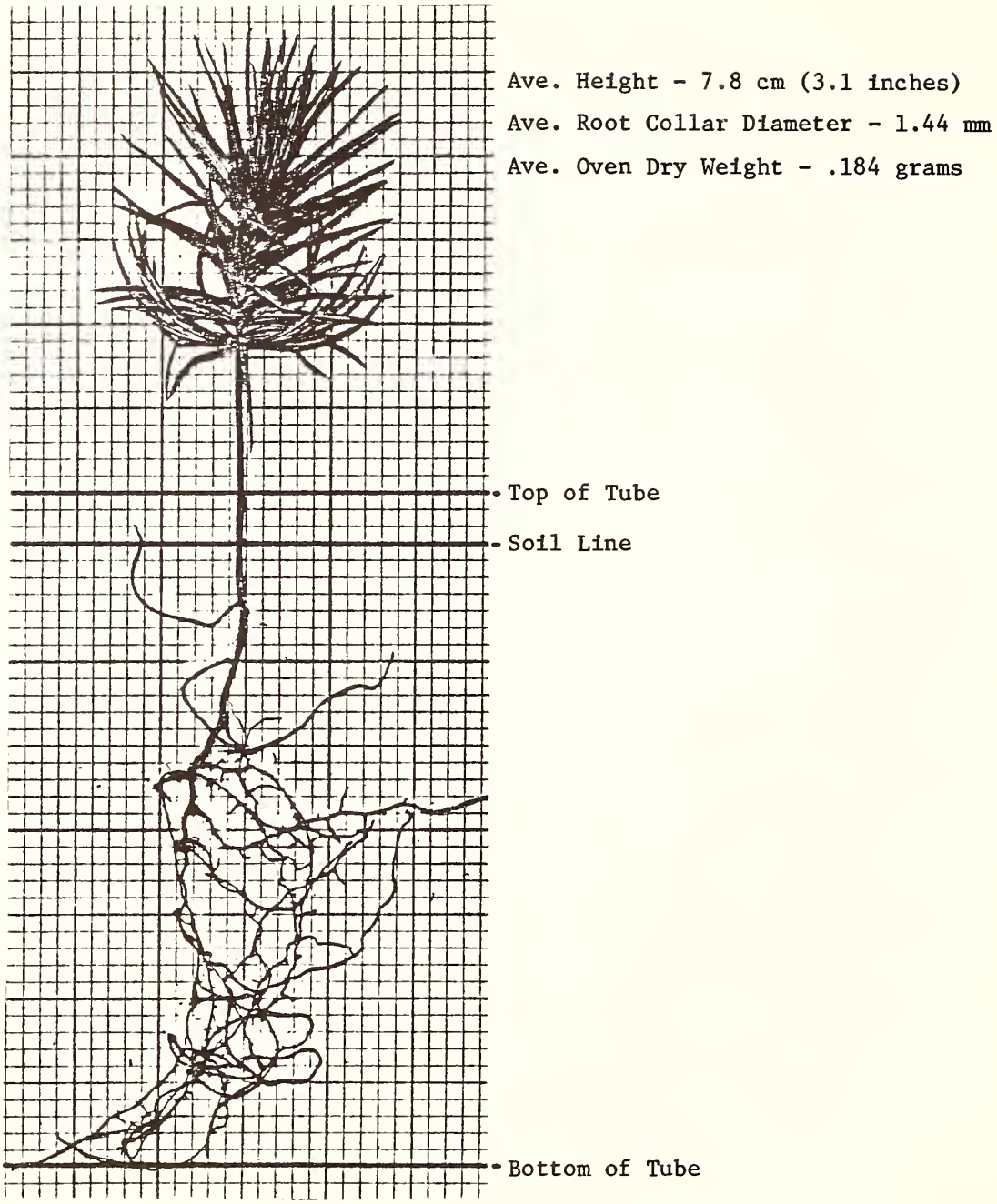
Ave. Height - 7.8 cm (3.1 inches)
Ave. Root Collar Diameter - 1.44 mm
Ave. Oven Dry Weight - .184 grams
Top of Tube
Soil Line
Bottom of Tube

Figure 1.--Average Size of 11 Weeks Old White Pine Tubelings When Planted on September 10, 1972.

Although frost heaving was experienced for almost two-thirds of the September test, only 15% of these seedlings were severely heaved 3 to 4 inches out of the soil. The slightly heaved tubelings were pushed back into the soil, but the severely heaved tubelings were removed and replanted with 2-0 seedlings the following April, to assure satisfactory stocking for the landowner (Goodwin 1975). Table 1 shows their survival and height growth, and a comparison of the 11 weeks old tubelings to the 2-0 bare root seedlings for the first five growing seasons. The 2-0 seedlings outgrew the tubelings by 3.2 feet. Survival for the 2-0 seedlings decreased from 93 to 90 percent whereas the tubeling survival decreased from 62 to 44 percent after five growing seasons.

A group of the best tubelings, which apparently had not frost heaved, averaged 5.0 feet compared to 8.1 feet for the tallest group of interplanted 2-0 seedlings. This gives some indication of the tubeling growth which might be expected without frost heaving.

Table 1.--Performance after 5 growing seasons of 11 weeks old September-planted white pine tubelings compared to spring planted 2-0 bare root seedlings

Growing Seasons	11 weeks old tubeling			2-0 bare root seedling		
	Survival	Ave. Height		Survival	Ave. Height	
(No.)	(%)	(cm)	(feet)	(%)	(cm)	(feet)
One	62	9.1	.3	93	27.4	.9
Two	44	18.3	.6	90	45.7	1.5
Three	44	36.6	1.2	90	88.4	2.9
Five	44	64.0	2.1	90	161.5	5.3

DISCUSSION AND IMPLICATIONS

Although the results of all but one of these tests were negative, certain indicators were obtained that are desirable for satisfactory survival and growth of white pine containerized seedlings. Thus these tests led to the following assumptions: (1) Containers should be used that will allow egress of lateral roots immediately upon planting; (2) a deeper container should be used to produce a longer rooted seedling; (3) the seedlings should be grown in the greenhouse from October to June for 30 to 32 weeks and preferably in a mountain location; (4) and the seedlings should be planted one inch deeper than the length of the root plug preferably in early June.

It is the author's opinion that these measures should help overcome the frost heaving and survival problem, as well as initiate faster height growth.

To test these assumptions, a new container was used. It is known as the ITW (Illinois Tool Works) container and was developed for Weyerhaeuser's Pacific Northwest conifers. It is one inch in diameter and six inches long as compared to 3/4 inch in diameter and 4 inches in length of the Rootrainer container. This container is no different from the tube for growing the seedlings in the greenhouse. However, on outplanting the seedlings, these containers behave similarly to styroblock or Rootrainer root plugs or to seedlings grown in biodegradable containers. A plastic sleeve is fastened around the container and when torn from the container, the lateral roots are immediately exposed to contact with the soil.

The Spencer-Lemaire Rootrainer container (Ferdinand type), which we are using operationally for other containerized pine species, was also used in this test. The Rootrainer container is somewhat smaller than the ITW container being 2 cm x 2 cm x 10 cm (3/4 x 3/4 x 4 inches) in size and containing 41 ml (2.5 cu.in.) of growing medium compared to 48 ml (2.9 cu.in) for the ITW container. A different growing medium of a 3 to 1 mix of sphagnum peat and horticultural grade vermiculite was used. This mix provides for less weight, less expense, and better drainage, aeration, and cation exchange than pure peat soil. Nutrients were applied with waterings.

These two types of root plug containers were seeded with two to three stratified seed per container on November 24, 1976, and were grown until May 5 in our Clayton production greenhouse with the winter Fraser fir crop. At age of 18 weeks, they were moved to the outdoor benches and conditioned for another 4 weeks. This was our first test of summer-planted white pine containerized seedlings.

The ITW seedlings were as large and as fully developed as our 1-0 nursery grown seedlings when planted on June 8. Table 2 gives a comparison of these 22 weeks old white pine ITW and Rootrainer seedlings with the 11 weeks old September-planted tubelings. Although the Rootrainer seedlings were about the same height as the tubelings, they were .6 mm (1/16 inch) larger in root collar diameter than the tubelings. The ITW seedlings, however, were 3.0 cm (1.2 inches) taller and were three times as large in root collar diameter as those of the tubelings. When planted, the ITW seedlings were almost the exact size as that for the tubelings after their first growing season. (Table 2).

This test was planted on a two acre portion of a 7 year old white pine plantation which had been killed by a wildfire two months earlier. A special ITW planting tool was used to plant the ITW containers. The plastic sleeves are removed from the container and the seedling is inserted in the bottom end of the tool. The hollow plastic-cone formed on the bottom of the container protrudes from the end of the dibble and aids in pushing the seedling into the soil. A plastic flange around the top of the cone locks the seedlings in the soil when the tool is removed. The Rootrainer seedlings were planted in a dibbled hole which was slightly larger and the same square shape as the root plug. Rootrainer root plugs are pulled out of the plastic container as they are planted, and the containers are reused for other crops.

Table 2.--Size comparison of three types of white pine containerized seedlings.

Type & Age of Seedling	Ave. Root Collar Dia. mm	inches	Ave. Top Height cm	inches	Length cm	inches	Gross Cavity Volume cu.cm	cu. inches
ITW 22 weeks	2.3	3/16	9.9	3.9	15.2	6.0	48	2.9
Rootrainer 22 weeks	1.8	2/16	7.4	2.9	10.1	4.0	41	2.5
Tubelings 11 weeks	1.2	1/16	6.9	2.7	10.1	4.0	37	2.3

Bare root 2-0 seedlings were planted to replace the dead or missing containerized seedlings the following April by our Forestation Unit. This was done to insure that the fire-killed portion of the plantation was replaced with a minimum of 500 living seedlings per acre according to their contract with the landowner.

Measurements, after almost two full growing seasons, were made for the containerized seedlings last week and also of the interplanted 2-0 seedlings after their first growing season. (Table 3)

Table 3.--Performance of 22 week old June planted white pine Rootrainer and ITW containerized seedlings after two growing seasons and of 2-0 seedlings after one growing season in North Carolina

Type of Seedling	Survival (%)	Mean Height (cm)	(Inches)
Rootrainers (Ferdinand type)	41	13.7	5.4
ITW containers (nose cone)	62	20.8	8.2
2-0 bare root	-	18.8	7.4

More mortality was found to have occurred for the containerized seedlings than was anticipated but it was mostly in patches. High mortality is believed to have been caused by the seedlings being planted in places where a deep, spongy duff occurred and by the dry summer when planted. Survival for the ITW seedlings was 62 percent compared to 41 percent for the Rootrainers. However, survival was good for the ITW seedlings and fairly good for the Rootrainers except for patches in the middle rows where it was practically nil. No frost heaving was observed as was the case with the tubelings. Survival was not determined for the 2-0 seedlings because it was so hard to see them under the dense cover of sprouts that

had come back after the fire. Normally, we can expect 80 to 90 percent survival of 2-0 white pine seedlings. Initially, the larger ITW seedlings are outperforming in growth the two-inch shorter Rootrainer plugs and tubelings and also the 2-0 seedlings. The ITW seedlings averaged 20.8 cm (8.2 inches) compared to 18.8 cm (7.4 inches) for the 2-0 seedlings and to 13.7 cm (5.4 inches) for the Rootrainers. (Table 3).

CONCLUSIONS

Tests conducted by the North Carolina Division of Forest Resources with white pine containerized seedlings show that they can be used to extend the planting season in the mountains through the summer and early fall months. Summer planting of the root-plug type of containerized seedlings overcomes the problem of frost heaving experienced with fall-planted tubelings and results in better growth. The older containerized seedlings (22 weeks) survive and grow better than younger 11 weeks old seedlings. Extending their growing period increased their root collar diameter more than it did their height, and a larger root collar is probably more important than increased height in the performance of white pine seedlings. If the crop is seeded in late September or early October, their growing period in containers can be increased to 32 weeks, thereby increasing the size of the seedlings even more for use in summer plantings. The ITW seedlings when planted were as large as 1-0 seedlings. Although their survival after two growing seasons in this particular test was not satisfactory, it is the author's opinion that this will not normally be a problem when they are planted on properly prepared sites during normal summer rainfall conditions. It is too early to know for certain, but it appears that their height growth may surpass or at least equal that of 2-0 seedlings planted during the following spring season but will probably be less than that of 2-0 seedlings planted during the preceeding spring season.

Presently the place of containerized seedlings in the reforestation scheme of white pine can best be relegated to extending the planting season, and to the immediate reinforcement planting or replanting of failures due to fire, spring drought, etc. There is a definite advantage in replanting during the same growing season as this helps prevent losing the benefit of the first year's site preparation. Further testing of techniques for growing older and larger white pine containerized seedlings in 30 to 32 weeks needs to be done before going to operational growing and planting of white pine containerized seedling crops. We are going to try this with approximately 75,000 Rootrainer seedlings next summer. The use of containerized seedlings should be looked at as another regeneration technique which can be used to supplement and complement the planting of white pine bare root seedlings.

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SIX PINES VARY WIDELY IN RESPONSE TO FERTILIZER AND MULCH ON SEVERELY ERODED SITES

Edward Buckner[1/]

Abstract.--Fertilizer and mulch stimulated the height growth of six pines more on the heavy clay substratum of a badly eroded Fullerton soil than on the loamy subsoil of an eroded Litz. Loblolly pine grew better without treatment and responded more to treatments than did the other pines. Results indicate that loblolly, pitch, and Virginia pines are suitable for stabilizing such severe sites while shortleaf, eastern white and scotch are not.

Additional keywords: Pinus virginiana Mill., P. echinata Mill., P. taeda L., P. rigida Mill., P. strobus L., P. sylvestris L., fertilizer, mulch, erosion.

Federal and state regulations requiring rapid stabilization of disturbed sites place high priority on the identification of suitable cover crops for surface mines, deep roadcuts, fills and other sites subject to erosion. For such purposes trees have an advantage over other types of vegetation because: 1) elaborate site preperation is not necessary, 2) permanent cover is provided requiring little or no maintenance, 3) deep roots protect against sloughing and landslides (Corbett and Rice, 1966), 4) establishment on the poorest sites is less difficult, and 5) establishment and maintenance costs are less. A disadvantage of trees alone is that complete protection is not obtained until stand closure occurs.

Various tree species, both native and introduced, have been used on disturbed sites with highly variable results. The use of selected pines on the more severely disturbed sites seems logical as they are naturally found on the poorer sites in their native region and their evergreen habit provides year-around cover. Also, a variety of species is readily available as seedlings from state nurseries making large scale planting economically feasible.

Although pines have been widely used for site stabilization, the degree to which cultural treatments such as fertilization and mulching might improve their performance on the often difficult subsoils and substrata exposed through erosion and earth-moving activities is largely unknown.

METHODS

Six species of pine were planted at two planting sites in the Valley and Ridge physiographic province of East Tennessee near Oak Ridge in the spring of 1965 to test the influence of fertilizer and mulch on survival and growth. Both sites were severely eroded. The six pines were: loblolly (Pinus taeda L.), shortleaf (P. echinata Mill.), Virginia (P. virginia Mill.), pitch (P. rigida Mill.), eastern white (P. strobus L.), and scotch (P. sylvestris L.). Of these, Virginia and shortleaf are native to the immediate area, white and pitch

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are native to the nearby mountains, loblolly is native about 60 miles south while scotch is an exotic native of Europe. The planting sites were approximately 6 miles apart and both had a southern aspect.

Site I: This, the harsher of the two sites, was a deep roadcut exposing the substratum of a Fullerton cherty silt loam. This parent material was derived from dolomitic limestone and had extremely poor physical properties. Chert fragments, that were residium from the eroded horizon, covered 70 to 90 percent of the surface with accumulations up to 12 inches or more in pockets and gullies. This tight clay substratum had a pH of 4.7, was low in P and very low in K according to agricultural standards. The absence of organic matter indicated very low N levels. Bulk density measurements ranged from 1.44 to 1.59 g/cc but these values were probably low as undisturbed samples were difficult to obtain due to the chert and moist samples of such plastic clays give low estimates due to shrinkage upon drying (Miller, 1966).

The slope was fairly uniform, varying between 30 and 35 percent. Gullies up to five feet deep carried off much of the rainfall due to the low permeability of the compact clay and the steep slope. Alluvial fans had developed at the slope base where gullies entered the road drainage system causing a serious maintenance problem. A few widely scattered Virginia and shortleaf pines were the only vegetation present 20 years after disturbance; these trees were removed prior to planting.

Site II: The exposed subsoil of a Litz loam (derived from shale) that had been severely eroded following agricultural abandonment approximately 25 years previously provided the second planting site. Although scattered remnants of an Ap horizon remained, the bedding planes of the shale parent rock were evident over most of the area.

Bulk density varied between 1.37 and 1.55 g/cc. Although P was very low, the site was less acid (pH 5.3) and K was very high according to agricultural standards. Nitrogen was low as there was little organic matter.

Slope within the planting area varied between 10 and 22 percent. Gullies up to four feet deep had developed along the lower margin. A stunted, 23-year-old Virginia-shortleaf pine stand had partially stabilized the area. Although variable, site index averaged 53 for shortleaf pine and 59 for Virginia pine. An herbaceous cover of grasses and honeysuckle (Lonicera japonica Thunb.) had become established beneath the open pine canopy. Portions of the planting area were still subject to sheet and gully erosion. Although site conditions were poor, both chemical and physical soil properties were better than on the roadbank.

Three replications of the following treatments were established on each planting site: 1) control, 2) 42 grams of 19-5-0 fertilizer placed in the closing hole at planting time, 3) an oat-straw mulch at the rate of approximately 20 tons per acre, and 4) both fertilizer and mulch at the above rates. Nitrogen was in the slowly available urea form and P was as concentrated superphosphate. K was not included as it has not been shown to limit tree growth in this region and high soil levels may inhibit water uptake by roots. Species plots containing 25 trees on the old field and 50 trees on the road-

bank were randomly arranged in each treatment plot. Trees were planted in March and April, 1965 on a 4 X 4 foot spacing.

RESULTS AND DISCUSSION

Survival: Initial survival (two seasons after planting) was about the same on both sites; 73 percent on the roadbank and 71 percent on the old field (Table 1). However, fertilizer significantly reduced the survival of all species except loblolly and pitch on the Fullerton clay (roadbank)

Table 1. Initial survival and change after 13 growing seasons of six pines planted on two severely eroded soils.

Pines	Fullerton clay			Litz loam		
	@ 2 years	@ 13 years	Change	@ 2 years	@ 13 years	Change
	---percent---					
Virginia	83	73	12	86	63	27
Shortleaf	57	53	7	59	44	25
White	63	50	21	61	47	23
Pitch	91	88	3	91	67	26
Loblolly	91	84	8	87	69	21
Scotch	54	35	35	45	41	9
Average	73	64	12	71	55	23

while it had little effect on survival on the sandier Litz loam (old field). Mortality since establishment has been greater on the old field, reducing survival to 55 percent (a 23 percent reduction), while it dropped to 64 percent (a 12 percent reduction) on the roadbank. However, continuing mortality on the old field reflects competition among trees while on the roadbank it was due largely to adverse soil physical properties.

Height Growth: Total height of all species 13 years after outplanting was significantly greater on the Litz loam than on the Fullerton clay (Figure 1). Loblolly pine was the tallest on both sites and was most sensitive to treatments, especially on the roadbank (Figure 2). When both fertilized and mulched it was the only species on the roadbank for which average growth over the 13-year study period was greater than one foot per year, while on the old field treated loblolly pine was averaging over two feet per year (Figure 2).

On the Fullerton clay treatments significantly improved the growth of all species, especially the pines native to the study county (Virginia, shortleaf and white). In contrast, on the Litz loam treatment effects were not significant although results suggest that they reduced the growth of Virginia pine while fertilizer alone stimulated the growth of white pine (Figure 2).

Loblolly pine survived as well, and grew better than the other pines tested on both sites. It was also the only species showing a consistent response to treatments on both sites. Although more susceptible than native pines to ice and snow damage, loblolly pine was more effective in stabilizing poor sites in the study area than were the native pines. Continuing mortality on the roadbank due to adverse site conditions was not a major problem, as was the case

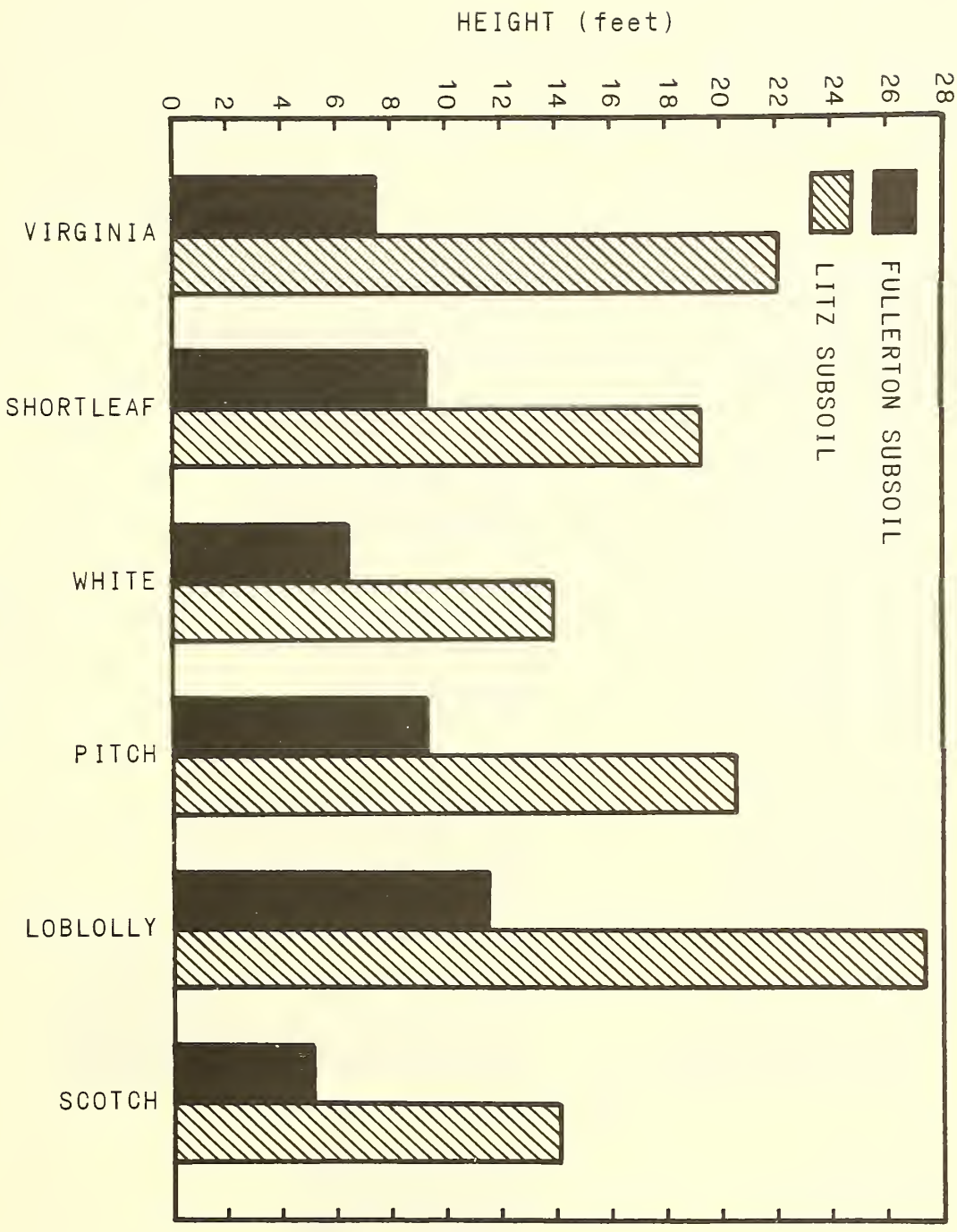

Figure 1. Comparative height of six pines after 13 growing seasons on Litz and Fullerton subsoils.

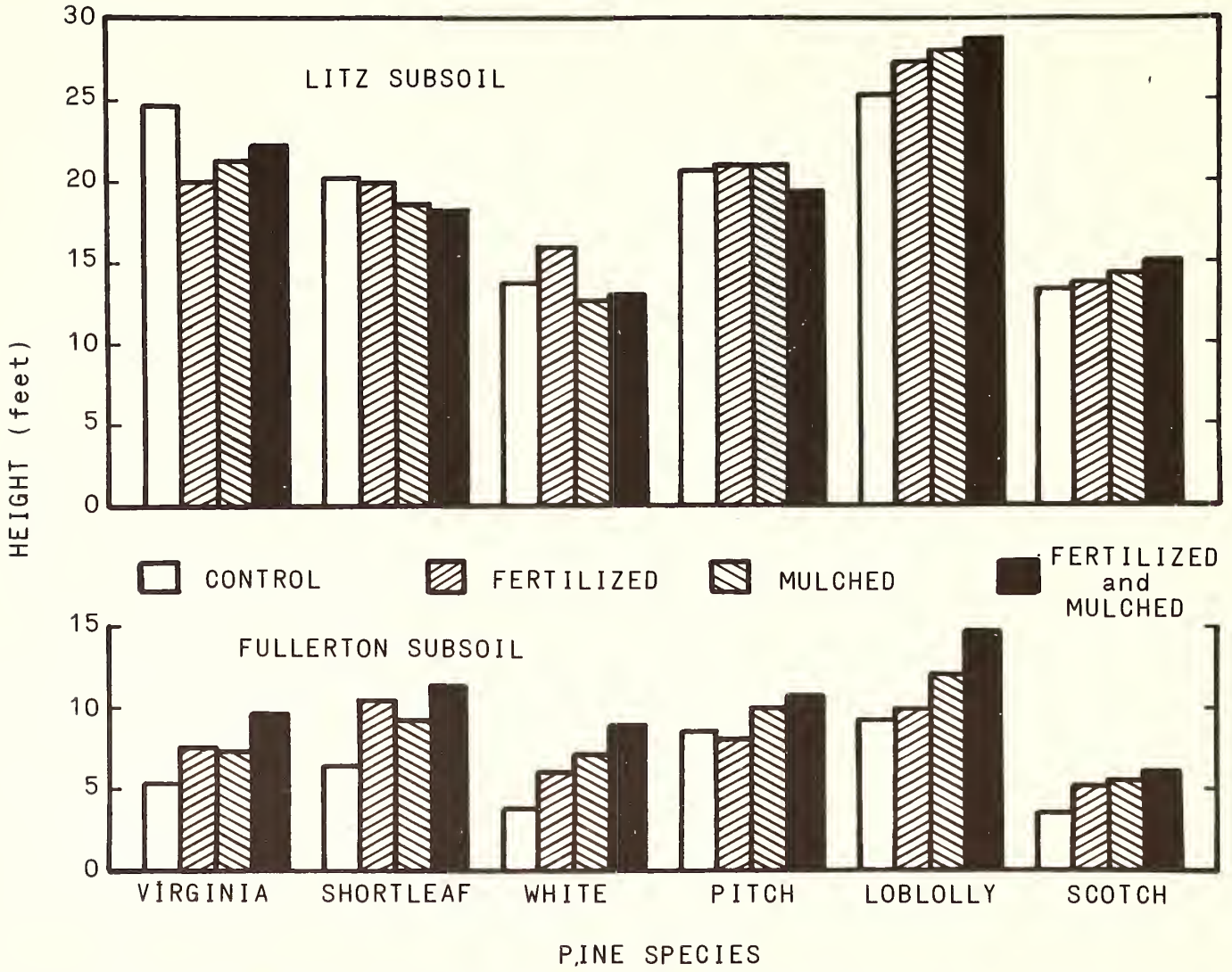

Figure 2. The total height of six pines after 13 growing seasons according to fertilizer and mulch treatments applied at planting time on Litz and Fullerton subsoils.

for several other pines.

Pitch pine survived and grew well on both sites. Although less responsive to treatments than loblolly pine, high initial survival was maintained over the study period (except mortality due to competition) making pitch pine well suited to stabilizing poor sites in the study region. Allen (1950) attributed such high survival in pitch pine to the early development of a prolific root system.

Of the two native pines, Virginia appeared better suited to both sites than shortleaf. It responded well to treatments on the Fullerton clay and, without treatment, grew almost as well as loblolly on the Litz loam, where treatments appeared to depress its growth. The primary disadvantage of shortleaf was low initial survival on both sites. It made satisfactory growth on the Litz loam and responded well to treatments on the Fullerton clay. Both survival and growth for white and scotch pine were too low to recommend them for site stabilization on such severe sites.

CONCLUSIONS

Recommended pines for planting on such severely disturbed sites are loblolly, pitch and Virginia. Fertilizers are more effective in stimulating growth on heavier soils but application at planting time will increase mortality. Overall growth is better on loamy subsoils but response to fertilization is smaller and of shorter duration.

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THE USE OF SOUTHERN PINES FOR SURFACE MINE RECLAMATION

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ABSTRACT

Pines of the interior South are native to much of the Appalachian and Interior coal provinces and have been used widely for mined-land reclamation. Species recommendations are often site specific and recognize location, site characteristics, properties of mine soil, compatibility with other vegetation, and land-use objectives. The basic technology does not differ significantly from that used routinely on natural soils. Special techniques may be required for evaluating the site, determining appropriate amendments, and selecting compatible herbaceous ground covers. Other systems may be used to improve survival and growth. The challenge to land managers is to recognize the productive capacity of mine soils and to use existing reclamation technology to maximize this potential.

In the Eastern United States species of pine are used widely for surface-mine reclamation. As pioneer species in secondary succession, they are adapted to the harsh environment of fresh mine soils. In general, the nutritional requirements of pine are low, and many species can tolerate the chemical extremes that occur in spoils. Mature pines provide a year-round screen and green cover that is esthetically pleasing. Potential product diversity and rapid growth also are incentives that encourage establishment of pine plantations.

Pines of the interior South are native to much of the Appalachian and Interior coal provinces and have been used widely for mined-land reclamation. Species used include: white pine (*Pinus strobus* L.); shortleaf pine (*Pinus echinata* Mill.); pitch pine (*Pinus rigida* Mill.); Virginia pine (*Pinus virginiana* Mill.); and loblolly pine (*Pinus taeda* L.).

Current surface-mine reforestation technology was developed after years of research and experience. In this paper I review important aspects relating to pines native to the interior South, including species selection, seeding and planting, and growth or yield.

SPECIES SELECTION

Since 1947 the Forest Service has conducted extensive research to determine the suitability of many tree species for use in reclaiming surface mines in midwestern and Appalachian states. The experimental sites represent a broad geographic range, diverse topography, and mine soils with different chemical and physical characteristics. These studies have demonstrated that many pine species are well adapted to reforestation of mined land and that interactions of species and site must be considered when selecting tree species.

Virginia pine is well adapted to a wide range of mine soils; it is one of the more acid-tolerant species and can survive on mine soils with a pH as low as 4.0. On many sites, the growth of Virginia pine has equaled or exceeded that of other pines. However, persistent branching and rapid taper limit its value for some wood products.

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Shortleaf pine also is considered an important tree for mined-land reforestation. It is not as acid tolerant as Virginia pine but can survive on mine soils with a pH of 4.5 or more. Growth and stem form are generally acceptable. Heavy infestations of tip moth often occur in young plantations, but the trees usually recover rapidly with little permanent damage.

The tolerance of pitch pine to acidic mine soils is similar to that of Virginia pine. Although not planted as frequently, it grows well on many sites. Pitch pine often has poor stem form, which limits its economic value.

White pine has shown variable results and is not recommended for planting on sites with a pH below 5.0. Characteristic slow growth for 3 or more years after planting limits its value for rapid site protection. The species can compete successfully with many herbaceous covers.

Loblolly pine grows well on many types of mine soil and generally has good stem form. Winter hardiness limits the geographic range in which it can be established. Seed source is important if this pine is planted beyond its natural range.

Evidence from early research has been used to develop recommendations for planting pine on mine soils in the eastern United States. Species recommendations are often site specific and recognize location, site characteristics, properties of mine soil, compatibility with other vegetation, and land-use objectives.

Recent improvements in seed collection, nursery culture, and stock grading have improved the quality of planting stock. It can be assumed that species recommendations based on early experiments still apply, but the survival, yield, and quality of trees will improve when better planting stock is used.

Genetics may also be used to improve species performance on mine soils. Evidence that seed source is a factor in the acid tolerance of Virginia pine was demonstrated in eastern Kentucky (Plass, 1973). Fifty-seven open-pollinated Virginia pine progeny from 10 natural stands located in Tennessee and Kentucky were evaluated in the field to determine whether genetic variability influences survival and growth on extremely acidic mine soils. After two growing seasons, survival, total height, and second-year growth were significantly better for some progeny. Differences in growth and survival also were related to the stand from which the seed for each progeny was collected.

These results indicate the importance of intraspecific variation in the growth and survival of Virginia pine on strongly acidic mine soils. Survival and growth can be improved by using planting stock grown from seed collected from selected stands. A breeding program, the traditional avenue of tree improvement, could produce genotypes specifically adapted to adverse sites.

SEEDING AND PLANTING

Seeding and planting activities include: (1) assessing mine soil characteristics that could affect methods of establishment; (2) using amendments to increase survival and growth; (3) selecting a compatible herbaceous cover; (4) considering appropriate planting arrangements; (5) planting seed

or seedlings. Each of these activities deserves consideration when contemplating the establishment of trees on mine soils. The importance of each is site specific and depends on site characteristics, planting objectives, and the anticipated intensity of management.

The physical characteristics of mine soils may determine the methods for establishing a plantation and selecting species. Important considerations are the size of the rock fragments and the predominant rock type. For example, on areas with large fragments of sandstone, establishment methods may be limited to direct seeding or mattock planting. Virginia or pitch pine may be the best choices since they are tap rooted species that are better adapted to coarse textured mine soils with a low capacity for retaining moisture. Recent improvements in the methods for earth movement and placement indicate that physical characteristics of surface mine soil can be controlled during the mining operation. However, there is concern that these methods may cause soil compaction; severely compacted mine soil could adversely affect tree establishment and growth.

Mine soil chemistry influences species choice, amendments required for establishment, and growth. At Iowa State University, simple correlation analyses indicated relationships between several chemical factors and survival (Lorio et al., 1965). For pitch pine there is a positive correlation with cation exchange capacity, available phosphorus, and the variable obtained by multiplying exchangeable aluminum by available phosphorus. There is a negative correlation for exchangeable and soluble bases, nitrifiable nitrogen, and soluble salts. For Virginia pine there is a positive correlation with the cation exchange capacity and a negative correlation with soluble salts.

Significant multiple regression variables predicting survival for pitch pine are nitrifiable nitrogen, cation exchange capacity, and available phosphorus. The yield of pitch pine is correlated with cation exchange capacity and exchangeable and soluble bases.

Models were developed to determine mine soil characteristics that had the greatest influence on the height growth of Virginia pine planted on an extremely acidic mine soil in eastern Kentucky (Thor et al., 1975). Three variables accounted for 25 percent of the variation in height: height growth increases with higher pH, lower conductivity, and greater exchangeable aluminum or acidity.

Fertilization research in Alabama showed that nitrogen and phosphorus were primary factors limiting pine growth on acidic mine soils (Bengston et al., 1973). Phosphorus is considered the most limiting factor because there is a growth response with phosphorus, while the use of nitrogen alone is ineffective. The best growth response results when both nitrogen and phosphorus are used. This parallels mine soil fertilization research for herbaceous plant materials. The similarity in response for pine and herbaceous covers suggests that fertilization can benefit both types of plants.

Data from studies on adverse mine sites in Ohio, Virginia, and Kentucky show that pines of the interior South inoculated with the ectomycorrhizae fungus (*Pisolithus tinctorius*) before planting survive and grow significantly better than trees inoculated with other fungal symbionts (Marx, 1975).

A greenhouse study showed that the use of lime accelerated the growth of pine on mine soils with a pH between 3.5 and 4.0 (Plass, 1969). Shortleaf, Virginia, loblolly, and a pitch x loblolly hybrid responded to applications equivalent to 2 and 5 tons per acre. The greatest response occurred after an application of 5 tons per acre. An application rate of 10 tons per acre had a negative effect on growth. Pitch pine did not respond to liming. The use of lime to aid the establishment and growth of pine has not been adequately tested under field conditions.

Another strategy for improving the growth of pine on mine soils is the use of nitrogen-fixing trees and shrubs as nurse crops (Plass, 1977). Except for loblolly, all of the pines of the interior South grew significantly taller when planted in alternate rows with European black alder (*Alnus glutinosa* L.) Tree diameters also were larger, indicating that this planting method may reduce the rotation length. It is assumed that other nitrogen-fixing trees and shrubs can be used with similar results. Black locust (*Robinia pseudoacacia* L.) usually is not a desirable nurse crop because of its broad spreading crown, excessive root sprouting, and aggressive domination of the site.

The compatibility of pine with various herbaceous covers, although poorly documented, is an important factor in mined-land reclamation because Federal amd State laws require that an herbaceous cover be established on all surface-mined lands. A study in Kentucky showed the response of Virginia and loblolly pine to herbaceous covers--a grass cover and a mixture of grasses and legumes (Vogel, 1973). Neither herbaceous cover affected survival when compared to no cover. Tree growth was reduced by both covers for the first 3 years after planting. Thereafter, the trees growing in association with the legumes showed an acceleration of growth not observed in the grass-only cover. It was assumed the trees were able to use the nitrogen fixed by the legumes.

This research suggests several options for tree establishment in herbaceous cover. The trees and herbaceous cover should be seeded or planted at the same time. Mixtures should include a high percentage of selected legumes, and the use of competitive grasses should be avoided. Minimum seeding rates for herbaceous species and low rates of fertilizer, especially nitrogen, also may reduce competition. There is also evidence that certain pine species are less affected by herbaceous competition than others.

Establishing trees by direct seeding is an accepted practice on natural soils and on mine soils in the South. In the central and northern Appalachians, research indicates that this technique has potential (Plass, 1976). Shortleaf, white, Virginia, and loblolly pines have been seeded successfully in the interior South. Before direct seeding is widely accepted, more research will be required to determine whether one or more species should be seeded, and to determine the appropriate application rates for seed.

A greenhouse study showed that: (1) fine-textured mine soil may restrict the emergence pine seedlings; (2) species of pine vary in response to chemical and physical characteristics; (3) the use of phosphorus seems essential for satisfactory growth (Plass, 1974). In other research, fertilization with phosphorus reduced the percentage of seedlings lost to frost heaving after the first growing season (Zarger et al., 1973). Competition from herbaceous covers, which was discussed previously, also applies to direct-seeded pine.

GROWTH AND YIELD

The potential productive capacity of mine soils needs to be recognized. Existing plantations in the Appalachian region show that the growth of pine on some mine soils equals or exceeds that on associated natural soils. But other mine soils have a low potential productivity. Factors contributing to this may include extremes in pH, physical characteristics that limit growth, low fertility levels, and the absence of microorganisms. Many of these conditions can be identified from field or laboratory tests. The challenge to land managers is to recognize the productive potential of mine soils and to incorporate the most productive areas into management plans.

The yield from pine plantations growing on mined land in the Appalachians is poorly documented, but two reports from Alabama indicate the possible yields from mine soil plantations. A study of 18- to 30-year-old stands of southern pines on surface-mined land that had revegetated naturally showed an average volume of 740 ft^3 per acre (Lyle, 1976). The average volume per acre for growing stock of all species in this part of Alabama is 825 ft^3 per acre. This figure includes managed natural stands and plantations. And a 20-year-old experimental planting on unleveled spoils near Jasper, Alabama, averaged 20 cords per acre for loblolly pine and 17 cords per acre for shortleaf pine (Plass and Burton, 1967). It was estimated that a pulpwood cut could be made in these stands at age 25.

The importance of mined land for pulpwood production can be demonstrated by assuming that at least one-fourth (about 72,000 acres) of the existing disturbance from surface mining in Kentucky, Virginia, Tennessee, Alabama, and Georgia, has an acceptable productivity potential. If 25 cords per acre could be produced in 35-year-old plantations, the pulpwood production on this surface-mined land in these states would equal 1.8 million cords. This is a conservative figure because probably more than 25 percent of the total disturbed area is productive, and intensive management will shorten rotations and increase yields. Additional acreage will be disturbed each year and much of this can be planted to productive plantations.

SUMMARY

Establishing pine plantations on surface-mine disturbance should be encouraged. The basic technology does not differ significantly from that used routinely on natural soils. There are guidelines for special techniques for evaluating the site, selecting amendments, and developing compatible herbaceous ground covers. Research and experience will improve this technology.

On the poorer sites, pine plantations will provide erosion control, site protection, and esthetic improvements. The more productive sites offer opportunities for economic benefits. Recognition of this potential and imaginative management will develop the full potential of these areas.

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Economics and Management of Pines In Christmas Tree Plantations

by

R. L. McElwee and W. A. Leuschner[1]

Abstract

Successful Christmas tree production is dependent upon adequate biological, cultural and financial planning with reasonable expectations that sufficient labor and capital will be available to sustain the venture to maturity. When considering a Christmas tree enterprise, the grower must realize the management strategies actually employed are dependent upon the economics of many alternate management options.

This review develops the array of management options open to the prospective producer and follows with economic analyses which indicate the more profitable management decisions.

Introduction

The Southeast will soon see a dramatic increase in the numbers of regionally grown Christmas trees if Virginia is representative of other Southeastern states. In the last 12 months we have noted more requests for information and assistance in plantation establishment and management than in the previous five years. Most of these requests were from landowners interested in "small" family ventures, but there were also several prospective "large" producers who are considering initial plantations of several hundred acres, with possibility for expansion.

All the information initially sought was concerned with cultural requirements and economics, with scarcely a question about markets, insect and disease problems, risk, or labor availability. If we are unable to convince prospective growers initially with the importance of these risk and labor considerations, they are foremost on their minds within a year or two.

What, then, are the considerations that both the experienced and the new grower must face in initiating or expanding a Christmas tree venture? What are the management options which must be considered, alternatives investigated, and choices made in order to pursue the best course.

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Management Considerations

1. Preplanting

   a. Site Selection: The first decision facing the owner is choice of site. Oftentimes the new grower is restricted to presently owned lands and thus limited to a predetermined site (Kidd, et. al., 1975). However, if land for Christmas trees is to be purchased, or if choices are available between locations within existing ownership, several factors must be considered:

      (1) Topography - Sites should not be too steep for mechanization, although absolutely flat land is not necessary. Cultural and harvesting activities are often most efficiently accomplished by tractor drawn equipment and sites in excess of 15 percent slope are difficult to traverse. It may also require longer to produce saleable trees on extremely steep land because of uneven branch distribution in the lower whirls (Kidd, et. al., 1975).

      (2) Site Productivity - The site's ability to sustain a satisfactory rate of growth is a most important consideration. Productivity is largely determined by soil fertility and soil-moisture relationships. Pines perform best on a moist, well-drained fertile site but require less fertility and moisture for satisfactory growth than spruces and firs. It may be possible to reduce rotation length on a higher site, but internodal length must be controlled to assure quality trees.

   b. Species: The species planted hinges on biological potential of species; seedling availability; production costs; insects, disease, and air pollution hazards; species preferences in anticipated markets; and to some degree the operator's personal preference. As an example, we have only limited areas in Virginia where Fraser fir is readily adapted but there are larger suitable areas for this species in North Carolina, Tennessee and other states. Consequently, much Virginia production is limited to white and Scotch pine. Thus far little interest is shown in Virginia pine, a species which seemingly holds promise in other states. Most of our production is a mixture of white and Scotch pine east of the Blue Ridge, and primarily white pine west of the Blue Ridge.

   c. Seed Source: The proper source of seed can be critical in any plantation. It has been established for many species that growth rates, form,disease and insect resistance, time of bud break, color, and other important characteristics are controlled genetically. Improvement in these characteristics can be made through proper choices of seed source. Definitive information is not available for all characteristics and all species but seed source should be considered whenever possible. We advise using seed sources originating as near the planting location as possible when information is not available. Additional gain within a seed source can be obtained by taking advantage of tree-to-tree variation. More tree-to-tree variation is found within some species and characteristics than might be found between seed sources. It is highly desirable that seed be used only from those individuals having the desired characteristics if the

grower has the latitude to choose. Such selection is extremely important if local, state, or regional seed orchards are being established.

d. Cover: Existing cover on a prospective site can increase the site preparation expense and severely restrict the financial returns. Land relatively free of rocks, large trees, brush, stumps, and fence rows is preferred(Brown, 1976). The site must be prepared prior to planting to meet both the biological needs of seedlings and to sustain the machinery to be used for plantation culture and harvesting if an old field is unavailable.

e. Spacing: Trees should be planted in a square or rectangular pattern in straight rows to accommodate cultural practices. The chosen tree spacing is a compromise between biological maximization of trees per acre and the equipment to be used in cultural activities.

Many growers prefer to use a 5 X 5 foot spacing, or 1740 trees per acre where land is expensive. This close spacing, however, can lead to clearance problems for machinery used in mowing and spraying. We recommend a minimum spacing, therefore, of at least 6 X 5. Tractors, spray equipment and mowers are much more maneuverable at a six foot or greater spacing with less risk of damaging or destroying trees and the wider the spacing, the faster equipment can move. This is attained, of course, with fewer trees per acre and subsequent reduced gross revenues. A 6 X 6 foot spacing has 500 fewer trees per acre than 5 X 5 foot and a 6 X 7 foot spacing has 700 fewer trees.

2. Post-Planting

Many decisions must be made which directly affect the economics of the Christmas tree enterprise following stand establishment. Many should be tentatively made prior to plantation establishment, particularly if an economic analysis is used in the initial investment decision. These post-planting cultural decisions include:

a. Replanting: The value of spot replanting is questionable in timber rotations but appears justifiable for Christmas tree rotations. Most growers spot replant seedlings which do not survive the first year. Although this practice is inexpensive compared to the increased returns from additional saleable trees, the expense of this extra year often required to produce the additional trees should be considered.

b. Weed Control: Weeds, grasses and herbaceous vegetation will strongly compete with seedlings for available water, nutrients and light. This competition will severely restrict the growth of young seedlings or kill them outright if not controlled. In older plantations, weeds compete for moisture and nutrients and are a fire hazard. Combinations of mulches, chemical sprays, hand weeding and mowing may be used during the life of the plantation. The frequency and methods of control will influence annual costs and the final profits picture.

c. Fertilization: Supplemental nutrients are necessary to maintain satisfactory growth rates on most sites. We advise all growers to base formulation and rates on soils analyses beginning the second growing

season following planting. We know the least and feel the most uncomfortable in recommending proper nutrient levels, reflecting our lack of knowledge concerning nutritional needs of woody plants.

d. Shearing: The necessity for annual shearing beginning in year three or four for tree quality is scarcely debatable. However, the grower or prospective grower must consider shearing methods and labor availability during the spring when shearing must be done. The total labor requirements must be assured if quality trees are to be realized and the availability of shearing labor often limits plantation expansion.

e. Pest Control: Growers must be aware of the insects and diseases which may invade their plantations. The possibility of control needs must be recognized and sufficient funds and labor kept available to assure control even though needs cannot be predicted precisely.

There appears to be a genetically controlled susceptibility to atmospheric pollution with some species, particularly white pine. Pollution losses must be recognized as management risks until resistant stocks become available. Partial recovery from pollution damage can be obtained by increased fertilization (Skelly and Will, 1974).

Economic Considerations

After all alternatives have been investigated and management regimes tentatively set, the "go-no-go" decision about establishing or expanding a plantation usually depends on a financial analysis. Financial analyses have been made using several different methods. For instance, Rudolph (1972) compounds costs forward from the year they occur until the end of the rotation at stated interest rates. He calls this the net income per crop. Gill and Loope (1970) follow similar techniques and call their answer the net income at rotation age. Both of these techniques calculate the investment's value in terms of the dollars at the end of the rotation, a Future Net Worth.

Leuschner and Sellers (1975) performed financial analyses by discounting costs and revenues back to today's dollar value, a Present Net Worth. They also calculated the Internal Rate of Return (IRR) in their analysis. IRR is compound interest rate earned by the investment and is the interest rate at which Present Net Worth equals zero. Leuschner and Sellers also projected an internal cash flow summary to help plan for monetary resources to meet required outlays. This is an important analysis for the small investor with limited resources as well as the larger investor.

Growers often elect to disregard land value in financial analyses if they already own the property. This is not a good financial procedure because it ignores the possibility of selling the land and re-investing the proceeds, for example, in eight percent Certificates of Deposit. Land costs should be calculated to more nearly reflect the venture's true profitability, even though the apparent return on investment is reduced.

So far as possible, all costs and returns must be realistically estimated in the financial analysis. The analysis below, modified from Leuschner and Sellers (1975) assumes a 6 X 6 foot spacing, 5 acre white pine plantation on an 8 year rotation, a common situation in our area. Costs vary with both time and location but a prospective grower can substitute his own costs using this example to estimate the financial desirability of investing in Christmas trees.

Table 1 - Example Financial Analysis for 5 Acre White Pine Christmas Tree Plantation (Figures rounded to the nearest dollar).

Year	Operation	Units		Total Dollars
		Number	$/Unit	
1	Buy land	5a	500	-2500
	Site prepare	5a	35	- 175
	Hand plant	6M	36	- 216
	Tools, taxes, supervision, etc.			- 35
		Total Year 1		-2926
2	Replant mortality	.6M	45	- 27
	Vegetation control, mow	15a	12	- 180
	Property taxes			- 20
		Total Year 2		- 227
3	Shear and prune	5.4M	65	- 351
	Vegetation control, mow	15a	12	- 180
	Vegetation control, spray	5.4M	18	- 97
	Property taxes			- 20
		Total Year 3		- 648
4	Shear and prune	5.2M	65	- 338
	Vegetation control	15a	12	- 180
	Insect control	2M	20	- 40
	Property taxes			- 20
		Total Year 4		- 578
5	Shear	5M	65	- 325
	Vegetation control	15a	12	- 180
	Property taxes			- 20
		Total Year 5		- 525
6	Shear	5M	65	- 325
	Vegetation control	15a	12	- 180
	Insect control	2.5M	20	- 50
	Property taxes			- 20
		Total Year 6		- 575

Year	Operation	Units Number	Units $/Unit	Total Dollars
7	Shear	5M	65	- 325
	Vegetation control	15a	12	- 180
	Broadcast fertilize	5a	30	- 150
	Property tax			- 20
	Sell trees	800	5.50	+4400
		Total Year 7		+3725
8	Shear	4.0M	65	- 260
	Vegetation control	15a	12	- 180
	Property tax			- 20
	Sell trees	4.0M	5 net	+20,000
	Sell land			+ 2.500
		Total Year 8		+22,040
	Total Year 8			+20,286

This cost and revenue tabulation provides the raw data for further analysis. Leuschner and Sellers (1975) demonstrate methods for computing the Present Net Worth and Internal Rate of Return from these data. They have estimated, using similar analysis, that rates of return for Christmas tree plantations vary between 13 and 42 percent, a satisfactory return for most investors.

Cash flow summaries for single and multiple years can also be calculated from these data. Cash flow summaries are vital to the small investor to plan the annual cash outlays needed prior to any returns being realized from the sale of trees. All potential investors in Christmas tree operations should prepare cash flow summaries until sufficient returns are realized for the operation to be self-supporting. For example, a simple cash flow summary for the above cost tabulations is:

Year	Total Cost	Total Revenue	Yearly Net Cash Flow	Accumulated Net Cash Flow
1	2926	0	- 2,926	- 2,926
2	227	0	- 227	- 3,153
3	648	0	- 648	- 3,801
4	578	0	- 578	- 4,379
5	525	0	- 525	- 4,904
6	575	0	- 575	- 5,479
7	675	4,400	+ 3,725	- 1,754
8	460	22,500	+22,040	+20,286

In this example, the investor must be prepared to invest the amounts shown in the yearly net cash flow column through the sixth year. It is not until the seventh year that any portion of the investment is recouped and only in the eighth year that income exceeds total investment.

Conclusion

The need for adequate biological and financial planning cannot be ignored. These two aspects interact and must be considered together if satisfactory plans are to be formed. Christmas tree growing is not simply a pleasant way to supplement retirement income or to obtain spare cash from otherwise idle acres. It is a venture which will fail and cost you money unless it is approached on a businesslike basis with knowledge of both its biological and financial requirements.

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THE CULTURE OF VIRGINIA PINE FOR CHRISTMAS TREES

George Brown, Jr.

ABSTRACT

Virginia pines from a west Jefferson County, Alabama seed source have been successfully cultured throughout the south for Christmas tree production. Cultural practices specific to this strain are discussed. Results of shearing experiments indicate that the diameter of the sheared branch affects the number of buds set. Control of the pine tip moths is necessary to produce quality Christmas trees.

INTRODUCTION

Virginia pine *(Pinus virginiana)* has been accepted as a Christmas tree species from Georgia to Texas. Because it is native from Long Island to central Alabama (Harlow and Harrar, 1968), many landowners north of the above belt of southern states are interested in the Virginia pine as a potential Christmas tree species. The objective of this paper is to discuss the culture of Virginia pine in the production of Christmas trees. General cultural practices which apply to most Christmas tree species are not discussed. The information presented here is based solely on research and experiences of southern growers. The culture of Virginia pine in more northern areas will not be identical to the southern areas, and results of cultural practices may be different.

One of the main reasons for these differences is because most southern Virginia pine growers obtain their seedlings from a single source, the Kimberly-Clark Corporation in Coosa Pines, Alabama. From 1958 to 1960, personnel from the Kimberly-Clark Corporation selected parents from west Jefferson county, Alabama. These parents were selected based on favorable pulpwood characteristics. In 1961, twenty-seven clones were grafted to establish a seed orchard. During the early 70's, eight of the original clones were selected based on Christmas tree characteristics. The remaining clones were rogued from the orchard, leaving only the desired parents for seed production. The Kimberly-Clark Corporation plans to produce three million Virginia pine Christmas tree seedlings in 1979.

This strain of Virginia pine is somewhat different from what is considered to be typical for this species. The selected trees tend to be straighter and taller. On a relatively poor site, 30 year old trees ranged from 60 to 80 feet in total height. The bark is typically grey in comparison to the normal reddish brown. In a study of the phenology of the flowering of Virginia pines from 5 southern states, Dr. James Goggins of Auburn University found that the receptivity of female strobili of this strain begins before any of the trees from the other four states. Of more importance is the fact that most of the Alabama trees complete their female flowering cycle prior to the pollen production of the other sources (Figure 1). If individuals from the Alabama strain were used in a seed orchard along with selected individuals from other states, there will be very little crossing between the Alabama trees and the others. This is especially true if seed is collected from only the Alabama trees.

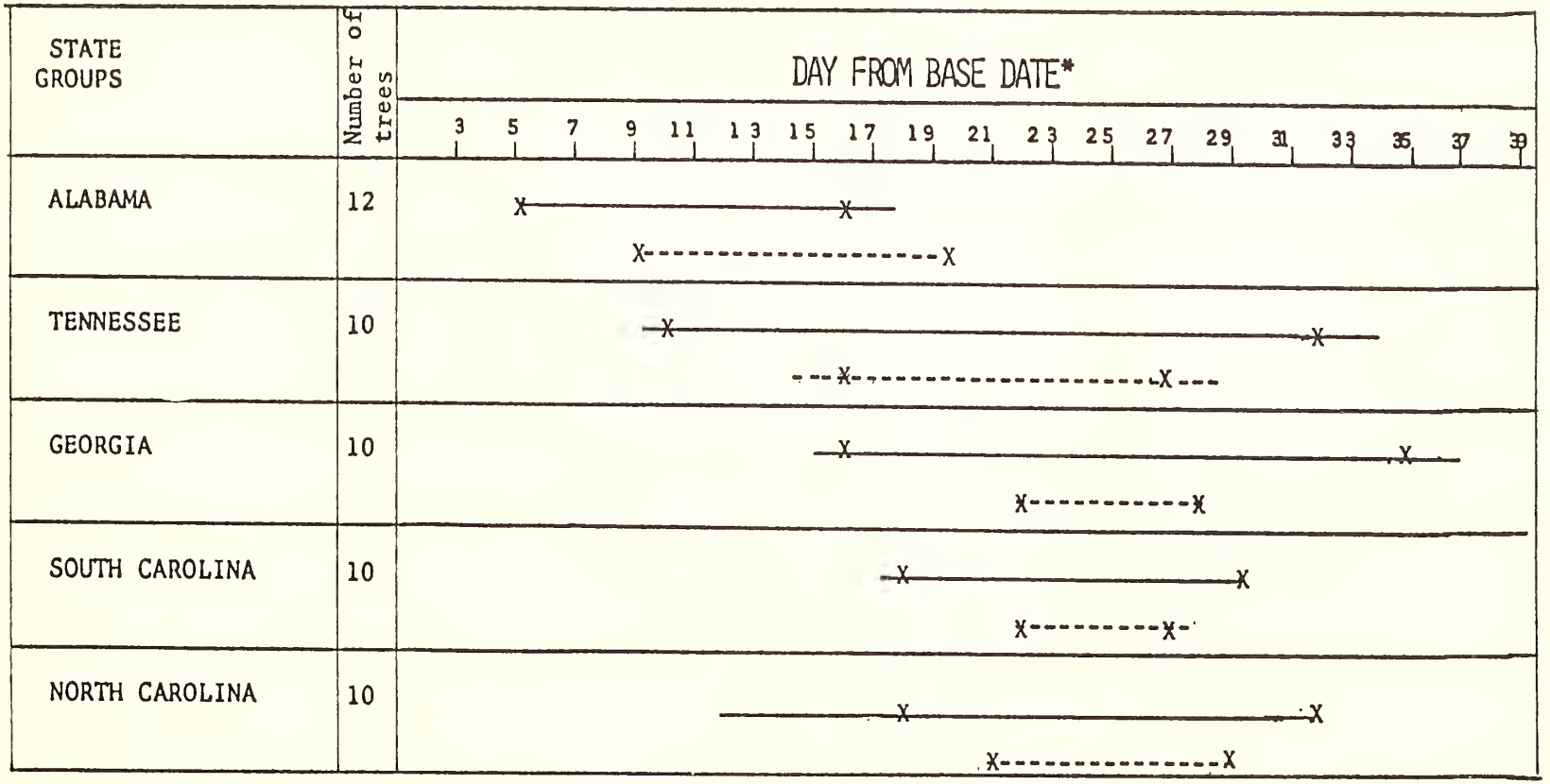
SITE, SELECTION AND PREPARATION

Virginia pines grow best on well drained, moderately fertile soil. They can be grown on infertile, dry sites, but with reduced growth. Poorly drained sites should be avoided (Box and Foil, 1968; Murray, 1976). Virginia pine is one of the least tolerant species to shade and should not be planted within fifty feet of dense woods (Lang, 1978).

Most southern growers have planted their seedlings in abandoned agricultural land. The most common and recommended practice is to cultivate the site the fall prior to planting. The cultivation reduces initial weed growth and smooths any furrows left in the field from previous crops. Fertilization is not generally recommended except for critically low nutrients, usually phosphorus for heavy clay soils. Use of a complete fertilizer usually increases weed control problems more than it stimulates tree growth. Fertilization may be profitable in the future if more efficient herbicides are developed.

PLANTING PRACTICES

The roots of 1-0 Virginia pine seedlings branch and become fairly fibrous below the root collar. Once planted, the root system will not support the seedling in an upright position. To avoid leaning seedlings, Virginia pines should be planted with enough of the stem in the ground to insure adequate support. This will normally include up to one inch above the root collar. Many seedlings will still have a tendency to lean over or grow crooked. A few growers prevent this by staking all trees shortly after planting. Another corrective procedure is to straighten the seedling and repack the soil around the base two months after planting. Trees found to be leaning or crooked after the first growing season should be staked.



*BASE DATE: MARCH 11

———— FEMALE STROBILI

- - - - - - - - - - - - MALE STROBILI

FIGURE 1: PERIODS DURING WHICH MORE THAN 20% (—X—DENOTES 30%) OF TREES POSSESSED POLLEN SHEDDING MALE STROBILI AND RECEPTIVE FEMALE STROBILI (DATA SOURCE: DR. JAMES GOGGINS, AUBURN UNIVERSITY).

Because of the density of sheared Virginia pine, their rapid growth, and their intolerance to shade, seedlings should not be planted too close to each other. A minimum spacing of 6' x 6' is usually recommended (Box and Foil, 1968; Holemo and Brown, 1977; Murray, 1976).

WEED CONTROL

The importance of weed control as a cultural practice cannot be stressed enough. Lack of weed control decreases seedling growth and deforms the bases of older trees.

Weed control on Virginia pine plantations is similar to most other Christmas tree plantations in that usually a combination of herbicides with mowing is used. However, due to the relative newness of the Christmas tree industry in the south, there are not many herbicides which have been tested, registered, and are available for use by the grower. Mr. Turner Davis will be presenting information on research and new developments with herbicides.

SHEARING

During the first two years, the shaping of a Virginia pine as a Christmas tree is similar to other pine species. The main objective is to eliminate double leaders and maintain a straight, central stem. Beginning in the third growing season, Virginia pine shearing practices become unique.

Experiments conducted by Davis in Georgia have demonstrated that the optimum time for a single summer shearing is normally during the middle of July (Davis, 1972). Due to the relatively fast growth of Virginia pine, two shearings are recommended during the third and fourth growing seasons in Georgia and Alabama. The first shearing is conducted toward the end of April with a lighter shearing performed in July. A few growers who have experienced optimum conditions in southern Georgia and Alabama have found it necessary to shear once during the second growing season.

Several experiments have been conducted at Alabama A & M University to determine the relative effectiveness of different shearing schedules. The two factors which were considered to be important when determining the effectiveness of a shearing were the number of buds stimulated by the shearing and the amount of growth which occurred after the tree has been sheared and prior to the next shearing.

The objective of the first set of experiments was to determine the effect of different shearing dates on the number of buds stimulated and the subsequent growth of the Virginia pines. The spring shearings were conducted at weekly intervals from the last week of April through the first week of June during 1976 and 1977. Forty terminal and forty lateral stems per date were

randomly selected for future measurements. The summer shearing was conducted from the beginning of July through the end of August, 1976, with twenty samples selected per date.

There were no significant differences among the total number of buds for each date, whether spring or summer sheared. Shearing on all dates stimulated a sufficient number of buds to insure adequate density. The average number of lateral buds ranged from 2.4 to 11.2 buds per shoot while the terminal buds ranged from 8.7 to 25.0 buds per shoot.

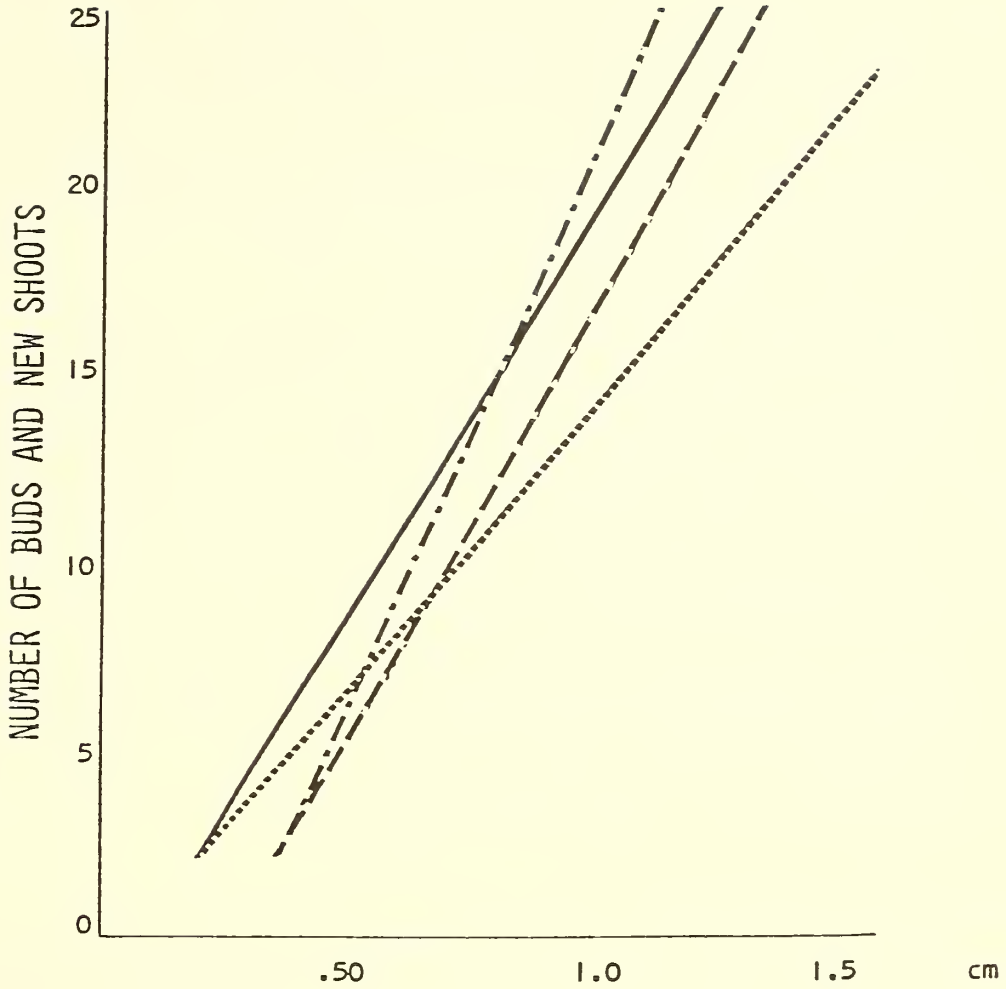
Growth of the longest new shoots per tree following the early spring or summer shearings was superior to all subsequent shearings. This was expected because the earlier shearing dates afford the shearing stimulated buds a longer period of growth prior to measurement. Average terminal growth from the April shearing was 16 cm by the first week of July, just prior to the summer touch-up shearing. The terminal growth was reduced approximately two centimeters for each week the shearing was delayed from the first April shearing. Growth following the mid-July shearing averaged 8 cm at the end of the growing season. Growth after the final shearing in late August averaged 2 cm.

Although there was no significant relationship between the date of shearing and the number of buds stimulated, there was a highly significant and positive correlation ($r = .70$ to $.86$) between the number of buds and the diameter of the sheared branch. As the branch diameter increased in both terminal and lateral branches, the number of buds stimulated also increased (Figure 2). As can be seen from Figure 2, the plantation site and the type of branch sheared (terminal vs lateral branches) affected the slope of the relationship. However, the correlation held true for both sites and both types of branches.

Virginia pine responds well to shearing. The primary factor which appears to determine the number of buds set is the diameter of the sheared branch. Branch size accounted for 49 to 74 percent of the variation in the numbers of buds, depending on plantation location and position of branch. Environmental factors, such as site quality and climatic conditions, may influence the bud set/diameter relationship. Based on the growth results and the branch diameter relationship observed in this study, the following guidelines for shearing Virginia pines can be recommended:

A. The spring shearing should be performed as soon as the trees have sufficient new growth (approximately one foot increase in height). Depending on weather conditions, this usually occurs about the end of April or early May in north Alabama.

B. The "tightness" of the shearing, or how deep into the tree one cuts, should be determined by the relative density of each tree. A tree which does not have the desired density should be sheared tighter than a tree with a dense crown. The tighter shearing will result in larger diameter branches being cut which will stimulate a greater number of buds.



——— Plantation 1, Laterals $\hat{y} = -2.4959 + 21.8268\ x,\ r = 0.76^{**}$

·—·—·— Plantation 1, Terminals $\hat{y} = -9.2163 + 30.1304\ x,\ r = 0.75^{**}$

····· Plantation 2, Laterals $\hat{y} = -1.3027 + 15.2781\ x,\ r = 0.86^{**}$

– — – — – Plantation 2, Terminals $\hat{y} = -6.5142 + 23.1509\ x,\ r = 0.70^{**}$

FIGURE 2: EFFECT OF BRANCH DIAMETER ON THE NUMBER OF BUDS AND NEW SHOOTS STIMULATED BY SHEARING

C. The summer shearing should be considered as a light "touch-up" shearing which gives the tree its final shape. This shearing should be finished early enough (mid-July) to allow new growth to cover the exposed stem scars resulting from the shearing.

By following acceptable shearing practices such as maintaining a sharp, clean knife, eliminating double leaders, etc. (Sharp and Thor, 1970; Touliatos, 1971) and using the above guidelines, Virginia pine can be shaped into a dense, well formed Christmas tree.

Lessons learned from the experience of a few growers include: (1) use only high quality knives when shearing Virginia pines and (2) the practice of cutting the terminals at a 45° angle may not be as important as it is with other species. The Virginia pine has stout,thick branches which cause low quality knives to first chip and then eventually break. In one situation, eight shearers started on a Saturday morning with twelve inexpensive knives and two high quality knives. By Sunday evening eight of the inexpensive knives had broken, whereas the two quality knives did not break. The same two knives have been used for three subsequent shearings and are still in good condition. The trimming of the top of the tree is probably the most important part of the shearing operation. However, even if the leader is cut a 45° angle, there will be several new shoots vying for leadership. All but one must be cut back to allow the selected one to develop into the terminal leader. This leader must also be cut, but at least four inches above its closest competitor.

MISCELLANEOUS PRACTICES

Virginia pines do not have the dark green to blue-green color desired by many customers. Therefore, it is almost necessary to spray with a commercial colorant. This spraying is usually accomplished during the first weeks of November in north Alabama. The relative density of the trees and the fact that they shed some of their needles each fall means that there will be an accumulation of dead needles inside the crown of each tree. Most of these needles fall out during harvest, baling and shipping. If the trees are sold directly to the customer, this natural occurrence should be explained to them.

Although protection is generally not considered to be a cultural practice, no general paper on Virginia pine Christmas trees would be complete without mentioning the most serious pest of this species: the pine tip moths (primarily the Nantucket pine tip moth). Because they always seem to hit the best leaders, they can cause a reduction in height growth and the stimulation of multiple leaders. This will cause crooked stems and will complicate the shearing operation. During 1978, in Alabama, we have not had one grower who had escaped this insect infestation. Our current recommendation to growers is to include a tip moth prevention and control program every year. Several insecticides which are applied as sprays are available which will kill emerging moths and newly laid eggs. However, these sprays must be timed

carefully to coincide with the peak emergence of the moth. They do not kill the larvae inside the tips, therefore, some damage cannot be avoided. A more effective and simpler method of control is to treat every tree with a systemic insecticide. The use of most of these systemic insecticides is restricted and a permit is required. Several growers throughout the south have effectively controlled the tip moths through the use of carbofuran (Furadan). This chemical must be covered after application for it is highly toxic to birds. At high rates of application, it is also toxic to the trees. On experimental plots, an application of one teaspoon per newly planted seedling and one tablespoon per tree one year after planting has caused chemical injury and up to twenty percent mortality of the trees. The highest rate tested six tablespoons per four year old tree showed no signs of chemical injury. Many growers are using the rates of one-half teaspoon per newly planted seedling, one teaspoon per tree after the first growing season, and then one tablespoon per tree each year thereafter. In southern Alabama and Georgia, two applications per year (one in January, the other in July) have been found to be necessary for adequate control of the tip moths on Virginia pine Christmas tree plantations.

CONCLUSION

Growers of Virginia pine have already proven the value of this species for Christmas tree production. There is still a lot to be learned and improvements to be made with our cultural practices. Several efforts are underway to select genetically superior trees which possess higher foliage density and improved natural form. Once these trees are incorporated into a seed orchard, the progency will require less shearing which also may shorten the rotation from five or six years to four or five years.

Growers contemplating beginning Virginia pine Christmas tree operations should be very selective about their planting stock. This species possesses a large amount of variation in growth, form and foliage density. Growers who plant seedlings not selected for Christmas tree production should expect a relatively high cull rate and may become disenchanted with this species. To be successful start with good planting stock and then apply the proper cultural practices. One without the other will not result in quality Virginia pine Christmas trees.

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RECENT DEVELOPMENT IN THE CULTURE OF WHITE PINE CHRISTMAS TREES

by

William T. Huxster, Jr.[1]

INTRODUCTION

Eastern white pine (Pinus Strobus) grows naturally throughout the Northeast, the Lake States and into Canada, and extends in fingers or patches into the Central States and down the Appalachian Mountains as far south as Georgia and Alabama. It is intermediate in tolerance, hardy, and thrives on deep, light, slightly acid loams but will grow under a variety of soil conditions. It is probably the most aggressive of the pine species. Because it will survive on many sites, doesn't mean it will produce a satisfactory Christmas tree. Successful plantations of Christmas trees have been grown in the deep well-drained soils of the Piedmont and Coastal Plains of North Carolina.

Eastern white pine can withstand summer temperature in excess of 100°F and very low winter temperatures. While its stem and branches are flexible they are more subject to breakage from ice accumulation than those of most eastern conifers. White pine is intolerant to drought and flooding and easily injured by fire. It is the most susceptible tree species to air pollution and salt spray. While it can endure many an impact and still survive it is subject to a greater array of diseases than any other North American species. It also has a host of insect problems.

Despite its tendency to wilt, limberness of limbs, poor consumer eye appeal when wet (needles cling together) the tree has gained in popularity with consumers throughout eastern and southern states. The species commands 30-40 percent of Christmas tree markets in some southern markets. A recent national survey estimates approximately 3 percent of the 30 million national Christmas tree marketed are white pine. In 1978 North Carolina growers planted in excess of 2 million white pine for Christmas trees. Admittedly a percentage of these will be managed as nursery ornamentals but over 50% are destined for the cut tree market. Add in what other states are planting, and the future contains significant increased availability of the species. Most retailers agree that a white pine must be of higher quality than Fraser fir or yellow pines to compete in numbers and price when sold on the same retail lot.

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What then is a quality or premium white pine Christmas tree? It is a straight single stem tree, conical in shape, 50-70 percent taper, strong bottom limbs, good on all four faces, so dense you cannot see the stem, single leader top, a uniform density with no holes or missing branches, one inch of handle per foot of height, free of insects and disease and a natural dark green to bluish green color, (not artificially colored) delivered to the customer in a fresh condition. White pine Christmas trees of this quality can compete with other species. In the future as production of Virginia pine and Fraser fir increase substantially and trees nationally are plentiful only the quality white pine will be purchased by the consumer.

Generally the technology exists to grow quality white pine, there are some problem areas and opportunities that will require research - let's examine some. Comments here are directed at the growing of cut Christmas trees. White pine nursery stock should be cultured in a somewhat different manner.

RECOMMENDED PRACTICES

Site Selection: First and foremost is the selection of the planting site. Within its natural range satisfactory growth of white pine is seldom hampered by variation in slope (gradient), aspect or elevation below 3500 feet. On Piedmont sites, white pine should be restricted to northern slopes containing deep well-drained soils. Avoid soils underlain by a relatively impervious layer of plastic clay within a foot of the surface.

Site Preparation: Adequate soil testing for nutrient levels and organic matter is the first step prior to preparing the site. Major nutrients such as nitrogen, phosphorus, potassium, calcium,magnesium and sulphur should be available at mid range fertility levels. Soil pH should be 5.5. Since lime and phosphate do not move readily in the soil they should be incorporated by disking in to a depth of 4 inches. Some growers having steep slopes are rototilling 20 inch strips on the contour. Fall tillage is preferred with the sowing of annual rye or some other small grain to be effectively used as a "nurse crop" at about one-half recommended cover crop rates. One important function of phosphate is that it lessens transplant shock. This can only occur if the phosphate is immediately available to the newly set tree. Eliminate all perennial plants such as tall grasses, vines, briars and brush prior to planting with a broad spectrum herbicide.

Selecting the Planting Stock: Choose the right planting stock in terms of age, balance of healthy top to root system, compact well developed fiberous root system, condition of the foliage, size of stem and buds. Vigorous plants mean earlier harvest and better survival. The seed source is critical and should be known. If possible, a white pine strain native to the area but selected for outstanding Christmas tree qualities such as branching, foliage color, growth and resistance to pest problems should be used. Several states have established seed orchards for improving the quality of future trees. Generally these were selected for timber production not Christmas trees.

Outplanting the Trees: While some sites require hand planting with dibble bar, mattock or spade, machine planting generally yields best survival and is more efficient. Trees may be cross-checked to permit cross mowing.

Spacing: Quality Christmas trees can only be grown if all branch tips receive sunlight. Therefore, spacing is a function of how high the tree is to be grown at harvest 4, 5, 7, 8, 9 feet or taller, desirable taper (40 to 90 percent allowed, 50-70 percent desirable) and the type of equipment used to mow them. Generally 8 foot-trees will require a minimum of 6 x 6 foot-spacing.

Weed Control: Keeping Christmas trees free of excessive weed, grass, and woody plant growth is one of the most expensive and time consuming cultural practices in growing quality white pine. Mowing helps keep competing plants under control yet prevents erosion between rows, reduces competition, rodents, and the fire hazard. Walk behind, and riding rotary mowers are generally used. The use of herbicides is an effective supplement and can be used in bands (on the contour) or spots around the tree. Application can be by manually or tractor powered equipment. Low and high pressure spray equipment is used. Preemergence and post-emergence types of herbicides are available. All pesticides, must be handled and applied properly according to their label. Since pesticide labelling varies somewhat by state no specific chemical will be mentioned here. Extension foresters and/or your county extension agent have local pesticide recommendations.

Response to most chemicals depends on time of application, soil composition, rainfall, temperature, size, kind and growing condition of target plants, rate of deterioration before being absorbed by the plant or in the soil, and the persistence of the chemical. Extremely heavy rates, wrong chemicals and continued use have adversely affected tree growth in some plantations. Reduction of target species may encourage the encroachment of other unwanted species. To control unwanted vegetation is not a simple matter.

Insect Control: Proper and timely application of pesticides can control most of the insect problems affecting white pine. Pales weevil can be reduced by removing pine stumps or spraying them. White pine weevils, pine bark aphids, pitch eating weevils, redheaded pine sawfly and white pine aphids can be controlled by thorough and timely spraying of an appropriate insecticide. Pesticides approved for use are generally becoming of the high volume of spray per acre types. Many growers are using hydraulic (200 psi with hose) or orchard air blast sprayers, both of which dictate the Christmas tree grower must be able to transport spray equipment within approximately 50 feet of each tree. Space for access roads must be allocated.

Disease Control: Most diseases of white pine cannot economically be controlled. The best approach is good sanitation, proper site selection and removal of infected trees as soon as identified. As mentioned earlier, white pine is subject to as many diseases as other species. Disease problems are magnified when the species is planted off site or out of its natural range.

Protection against Animals: Most domestic livestock and wild animals will damage or kill white pine. Deer, rabbits and rodents have caused severe damage. Most repellents have proven ineffective in the past. A spray of red pepper sauce and anti-desiccant is showing promising results in the northeast. The material as of now is not labeled for such use. Removal of the animals and in the case of rodents, the elimination of heavy grass cover is the only other practical means of control.

Shaping and Shearing: Timely shearing with a sharp cutting edge of current year's growth and tree vigor are the secret in developing optimum bud set for next year's growth of terminals and lateral branches. Shearing is treated in detail by Whitfield. While mechanization is the dream, most white pine shearing is accomplished manually with a 14-inch razor sharp knife. Each worker should be equipped with two knives, a pair of gloves and a leg guard, plus solvent to keep the cutting edges free of resin. Desired shape and density are largely controlled by shearing. Improper shearing is the biggest cause of poor quality white pine going to market.

OPPORTUNITIES TO IMPROVE QUALITY

Genetics Section: There is much evidence today that Christmas tree quality can be improved through genetic selection. Characteristics such as branching, foliage density, growth rates, resistance to pest problems, color and time of bud break are examples of gains which can be made through careful selection. These selections should be coordinated with genetic work being conducted on Forest Tree improvement.

The Role of Mycorrhizal: Research is being conducted and more should be encouraged on the use of specific beneficial mycorrhizal fungi in tree nurseries and in plantation management. Pisolithus tinetorius, an ectomycorrhizal fungus of many conifers, and oaks shows tremendous promise for improving survial and growth of trees on a variety of adverse sites. There are many species and strains. The potential does exist to artificially infest nursery soils to tailor roots of tree seedlings.

Irrigation: White pine has a higher requirement for soil and atmospheric moisture than do the hard pines. Certain marginal sites could become profitable with appropriate application of irrigation technology.

Growth Regulators: One of the biggest contributors to poor quality trees is inadequate bud set. While fertility is partially responsible, probably the biggest single cause is late shearing of individual trees. It has been demonstrated that certain growth hormones can stimulate latent bud development. When perfected, this technique can substantially increase tree quality and perhaps reduce the number of shearings required.

Nutrition: Little work has been done in specific nutrition schedules for certain type soils to grow optimum white pine Christmas trees at the least cost. Optimum combinations of specific nutrients, there form of application, timing of application and amounts, their influence on mycorrhizal development and the resulting effects on tree growth for Christmas tree quality should be determined.

Summary: There is evidence that Christmas tree growers are increasing their plantings of white pine along with other species. White pine quality must improve if its to continue to hold traditional markets and captive new ones. Existing cultural practices are adequate to produce quality trees if growers can practice them. However, there are real needs in improving genetic selection, understanding and application of mycorrhizal fungi, nutrition, use of growth regulators, and control of pests. Specific criteria should be developed and adopted for growing ball and burlap "living Christmas tree" white pine that will improve survival upon transplanting.

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HERBICIDE DEVELOPMENTS IN CHRISTMAS TREE CULTURE

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Abstract

A number of pre-emergence and post-emergence herbicides which have possible use in the production of Christmas trees throughout the South are discussed. Recent tests in middle Georgia and their results are outlined. Surflan @ 2 to 4 lbs/A combined with Simazine at similar rates looks extremely good as a pre-emergence treatment, while glyphosate (Roundup) looks very good as a post-emergence treatment. Dacthal @ 12-1/2 lbs/A + Simazine @ 4 lbs/A looked better than 10 other pre-emergence treatments in controlling both grasses and broadleaf weeds in 1978.

Introduction

Christmas tree production in Georgia is increasing at a faster rate than ever before. Since 1973, the number of growers has more than tripled and enthusiasm is high. The reason for this is due to a variety of factors. Growing conditions in Georgia and other southern states are ideal for good returns during a short period. Shipping costs are getting higher each year and locally grown trees are fresh when the customers receive them. Research on Christmas trees at the Georgia Experiment Station began over 15 years ago. Techniques have been developed to enable serious growers to grow top quality trees with several species, including Virginia pine (Pinus virginiana), formerly considered a "scrub" pine. At present, a "sellers market" prevails in Georgia with choose-and-cut operations beginning all over the state. The secret to making an excellent profit with all trees being sold is simple - grow a good quality tree. Very few trees are sold on the wholesale market since growers are "selling out" at retail prices on their farm. At the present rate of planting, wholesale trees should be on the market in greater numbers in 3 to 5 years.

Previous Studies

Excellent growing conditions for trees, unfortunately, mean faster growing weeds and grasses. The most important tasks of a successful grower include proper weed control, shearing, insect, and disease control. Excessive growth of weeds and grasses in plantations is one of the greatest problems for our producers. If some type of weed control is not carried out the result will be poor survival, slow growth, or low quality. This may be done by mowing, with chemicals, or a combination of the two. In most cases, cultivation has not proved to be very successful and extreme care must be used to prevent damage to tree roots.

Numerous chemical materials have been manufactured for use in many crops. Some of these have proven to be practical in Christmas tree production and in

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nurseries.[2] With such a large number of herbicide trials throughout the country, it is little wonder that a grower may get completely confused as to what should or can be used. Extreme care must be taken when using herbicides to make certain they are cleared for use. An applicator's license will be required to apply many of them. Each grower should check with a local Agricultural Extension Office, State Department of Agriculture, or other agency concerning a license, restricted uses of chemicals, and clearance for use. Applications should be made according to the label. It is impossible to find a single material which will control unwanted weeds and grasses under all circumstances. Non-selective or contact herbicides work rapidly in sunlight and plants may show injury within hours of treatment in sunny, warm weather. Ahrens (1974) found that tree foliage must be protected when using these. Reid and Davis (1975) developed a shielded herbicide applicator for applying these chemicals while protecting plant foliage. Herbicides may be classified as pre-emergence or post-emergence. Their effectiveness may vary by time of application, temperature, soil type, rainfall, or other factors. Some are much more toxic than others. A chemical may be safe to use in certain species of trees but not in others. It may be safe to spray over the tops of some trees with certain chemicals without tree injury, while the same chemicals may damage other species. Specific herbicides may control broadleaf weeds or grasses, but not both. Some will control only specific broadleaf weeds, but not others. It is possible to mix certain chemicals with better results. There are some herbicides with long-term effectiveness, but others last only a short time. Liquid and granular applications can be made. Some break down in the soil quicker than others; some are taken into plants only through the roots, while others are only effective through the foliage. To further confuse growers, several companies may sell the same chemical under different trade names.

For several years attempts have been made to come up with some type of economical weed control program for Georgia growers. It seems that every area of research requires a little something different. This is due to varied weeds, soil types, temperature, moisture, and species. In addition to finding a good control, one must be found that a grower can afford. Comments or recommendations given here are results from trials in Georgia, with some in other states. Some of these herbicides may not be cleared at this time and the labels on containers should be closely followed.

Discussion of Recent Studies

Table 1 gives the control percentages for 12 pre-emergence herbicide treatments in 1978, compared to check plots. All of these sprays were applied to 3-year-old Virginia and white pines on March 15. Ratings were made on June 16 and again on September 25. All treatments gave excellent crabgrass control up to June 16, but Kerb @ 3/4 lb. and 1-1/2 lbs. + Simazine @ 4 lbs.,

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2/ Trade names are used in this publication to provide specific information. Mention of a trade name does not constitute a guarantee of that product by the University of Georgia, nor does it imply an endorsement by the University over comparable products that are not named. A chemical mentioned in this report does not necessarily mean that it has been cleared for use by the Environmental Protection Agency.

Table 1. Herbicide Test in Three-Year-Old Virginia and White Pines in Middle Georgia.[a]

Treatment[c]	Control Rating June 16[b] Crabgrass (%)	Broadleaf[d] (%)	Control Rating Sept. 25 Crabgrass (%)	Broadleaf (%)
1. Check	0	0	0	0
2. Sward @ 3 lbs/A[e]	95	15	90	0
3. Sward @ 3 lbs/A + 2 lbs/A in mid-May	95	0	95	0
4. Sward @ 2 lbs/A + 2 lbs/A in mid-May	100	0	90	5
5. Sward @ 3 lbs/A + Simazine @ 4 lbs/A	100	90	95	75
6. Kerb @ 3/4 lbs/A +[f] Simazine @ 4 lbs/A	100	95	25	95
7. Kerb @ 1-1/2 lbs/A + Simazine @ 4 lbs/A	100	85	65	85
8. Betasan @ 10 lbs/A[g]	100	25	90	10
9. Betasan @ 10 lbs/A + Simazine @ 4 lbs/A	100	80	95	60
10. Dacthal @ 12-1/2 lbs/A[h]	95	30	95	30
11. Dacthal @ 12-1/2 lbs/A + Simazine @ 4 lbs/A	100	90	95	80
12. Simazine @ 4 lbs/A[i]	100	85	60	85

a/ Application on March 15. Summer was extremely dry. Soils heavy.
b/ Numbers indicate percentage control (90-100 = excellent, 80-90 = good, 70-80 = fair, below 70 = poor.
c/ Active ingredients
d/ Predominant broadleaf weed population: Crabgrass (*Digitaria sp.*), Johnsongrass (*Sorghum halepense*), prickly sida (*Sida spinosa*), morningglory (*Ipomoea hederacea*), horseweed (*Erigeron canadensis*), dandelion (*Taraxacum officinale*), whiteheath aster (*Aster pilosus*), and ragweed (*Ambrosia artemisiifolia*).
e/ Elanco product, EL-131 (50 WP)
f/ Rohm and Haas product (50 WP)
g/ Stauffer product, Prefar (4 lbs. EC/gal.)
h/ Diamond Shamrock product (W-75)
i/ Ciba-Geiby product (80-W)

and Simazine alone @ 4 lbs was poor by September 25. For broadleaf weed control, only treatments 5, 6 and 11 were excellent on June 16, with treatments 7, 9, and 12 good. By September 25, treatment 6 was still excellent for broadleaf control with 7, 11, and 12 good. All control percentages under 70 were considered poor. The best overall treatments for crabgrass and broadleaf weeds throughout the summer were 5 and 11.

Simazine (Princep WP,4G,8G). Simazine has been extensively used in the South as a pre-emergence herbicide. Rates have run from 2 to 6 lbs/A a.i. It is not effective after weeds have emerged in the spring, is relatively insoluble in water and is taken into plants through root systems. To be effective, precipitation is needed within a few weeks after application to move it into the soil. Four pounds have given adequate control of weeds in the Piedmont until about mid-summer. A second application, possibly in May, is necessary in most Georgia soils if simazine is used alone. In the past, growers have sprayed over the top without noticing any damage. A test was installed in March 1978, using 3 and 6 lbs/A over the tops of freshly planted Virginia and sand pines. The purpose was to determine any possible damage to new plantings. The same two rates were applied, using a shield to protect tree foliage. Table 2 shows significantly greater survival in Virginia pine check plots than all other treatments. This did not hold true for Georgia sand pine but did for Florida sand pine. From date of application (March 15) to June 9, 18.6 inches of rain fell. However, only 0.34 inches fell in 26 days following application. Then, almost 2 inches fell at once. These results are not conclusive and must be repeated. This is an indication that under certain climatic conditions, it is possible to get injury from herbicides which are generally safe. Putnam (1970) has recommended 2 to 4 lbs/A of Simazine for established plantings, with lower rates in sandy soils or on lining-out stock.

Atrazine has been used in some areas. It is slightly more soluble in water than simazine, and although most is absorbed through root systems of plants, some may be absorbed through leaves also. Due to these factors, atrazine could be more effective on larger and deeper rooted plants than simazine. However, the possibility of damage to seedlings is increased when it is applied over the seedlings, especially under high precipitation. In 1972, Oregon Christmas tree growers were doing a good job of weed control in Douglas fir (Pseudotsuga taxifolia) with a mixture of 4 to 6 lbs. of atrazine and 2 lbs. of 2,4-D amine, sprayed from the air in March. It should be clearly understood that a treatment such as this would not work with many species. In addition to checking the chemicals for clearance, tolerance tests must be checked on each species.

A combination of Modown[3] at 4 lbs/A and Devrinol[4] at 3 lbs/A has given good weed control in Alabama for short periods, up to 60 days, when applied over the top of young Virginia pines in March. Initial studies indicate that this rate was sufficient in sandy soils but may be a little low for heavier clay soils. These were registered in several southern states under Section 24(C) granted by EPA about 1977. At least one Alabama nursery has used this mixture over pine seedlings in recent years without injury. In 1978 south Georgia tests on sandy soil, 2 and 4 lbs/A of Devrinol mixed with simazine at

3/ Mobil Chemical pre-emergence product (Bifenox)
4/ Stauffer Chemical product (Napropamide)

the same rates gave fair weed control. This combination was better than simazine alone, probably due to the extremely low water solubility of Devrinol. Devrinol has excellent potential when incorporated into the soil prior to planting, but more studies are needed on this.

Table 2. Simazine Test in Newly Planted Virginia Pine (Pinus virginiana) and Sand Pine (Pinus clausa). [a]

Treatment	% Survival on June 9		
	Virginia Pine	Georgia Sand Pine	Florida Sand Pine
Check	100	65	90
Simazine @ 3 lbs. (using shield)	65	90	75
Simazine @ 3 lbs. (over top)	60	50	70
Simazine @ 6 lbs. (using shield)	50	70	55
Simazine @ 6 lbs. (over top)	85	70	55

a/ 1-0 stock used. Trees planted February 14 and herbicides applied March 15. Only 0.34" of rainfall in 26 days following applications.

Surflan (Oryzalin)[5] is one of the more promising pre-emergence herbicides in plantations, especially when used in combination with simazine. Recent tests in south Georgia sandy soils gave excellent results at 2 to 4 lbs/A combined with simazine at 2 to 4 lbs/A. Surflan has low water solubility, resists leaching, has a broader spectrum and is better for grass control than many other chemicals. Pigweed (Amaranthus retroflexus), a serious problem weed in south Georgia, is controlled very well with this combination. Simazine alone has a limited spectrum, limited grass control and is shortlived in this area. Connecticut researchers have recently been using surflan and simazine combinations in early spring with good success. This can be applied over the top of pines and many other species.

Kerb (Pronamide)[6] has been used for several years in most southern states. Good results have been reported when it is used at a rate up to 4 lbs/A in combination with simazine up to 4 lbs/A, applied over the top in February. Kerb has both pre-emergence and post-emergence activity, is absorbed through the roots, and moisture is essential to move it into the root zone. It is most active in medium textured soils of low organic material. The manufacturer recommends fall applications on Christmas trees. Michigan studies have indicated that there is very little danger of over-application and it does not control broadleaf weeds well when used alone.

Glyphosate (Roundup)[7] has probably given the best over-all results of any single material in Virginia and white pine plantations in Georgia. It is a non-selective, contact, post-emergence herbicide. Two, four, and six-year-old plantations were treated with 4, 6 and 9 lbs. of acid/A in mid-summer to

5/ Eli Lilly Company product
6/ Rohm and Haas product
7/ Monsanto Company product. Contains 4 lbs. of a.i. isopropylamine salt of N-(phosphonomethyl)glycine per U.S. gal. Equivalent to 3 lbs. per U.S. gal. of the acid, glyphosate.

determine if any tree damage would result from repeat applications. Lower branches were removed from some trees and some of the chemical was intentionally sprayed on the main stems. No apparent damage resulted except where foliage was hit when spraying. All rates gave excellent weed control and tree growth was not adversely affected. For best results, weeds and grasses should be growing well and leaf surfaces should be great enough to allow translocation. To conserve the chemical and do a good job, weeds and grasses may be mowed and then sprayed when they begin to grow again. Generally, 1 lb. of acid/A is sufficient to kill most weeds. No wetting agent or surfactant is required. Tree foliage should be protected with some type of shield. Bermudagrass (Cynodon dactylon) will require up to 4 lbs. of acid/A, with about 2 lbs. at two different times during the summer. Johnsongrass and fescue are controlled very well at rates of 1 to 2 lbs. of acid/A. As a general rule for spraying most herbicides, at least 20 gallons of water should be used per acre. Twenty to forty gallons of water were used in Georgia tests. In Connecticut tests, Roundup has been sprayed over the tops of Fraser fir (Abies fraseri) and some spruce (Picea) species during September with little or no apparent tree damage. Growers are warned to not attempt this in the south with our species and climate. Our growing season is longer and southern pines are likely to be damaged or killed by over-the-top sprays. A number of plants including the rose family, pyracantha, peaches, pears, plums, quince, baldcypress and forsythia are very sensitive to Roundup and they could be damaged even if the foliage is protected. Southern pines and most other Christmas tree species are apparently not sensitive. Georgia tests have shown that rates from 1 qt. to 5 qts/A in 20 to 40 gallons of water may be used, depending on the types of weeds or grasses to kill. Results are noticeable within 10 to 15 days. Many people who only have hand sprayers desire guidelines on mixing and spraying Roundup when cleared for their area. They are unable to calibrate exact applications such as those with spray equipment. Table 3 gives general recommendations for these small growers.

Table 3. Applying Roundup With Hand Sprayers.[a]

Amount of water used per acre	Amount of Roundup to mix per gal. of water	Number of trees you[b] should spray with 1 gal. mix
20 gallons	2.1 oz. (63.1 ml.)	156
25 gallons	1.7 oz. (50.5 ml.)	124
30 gallons[c]	1.4 oz. (42.0 ml.)	104
35 gallons	1.2 oz. (36.1 ml.)	89
40 gallons	1.1 oz. (31.6 ml.)	78

a/ Using 1 lb. of acid/A (1/3 gal.). Check for clearance prior to applying this chemical.

b/ Spraying a one foot strip down each side of a row of plants (Total of 2 feet wide per row) with trees spaced 7 feet apart.

c/ A good mix for general use.

Paraquat[8] is another non-selective, contact herbicide with rapid contact action. It is soluble in water and much more effective when using a small amount of surfactant or wetting agent (1 to 2 ml/gal. of water). Excellent results have been obtained within a few days, using 25 ml. of paraquat per gallon of water. It kills weeds and grasses down to ground level but does not

8/ Chevron Chemical Company product, 2 lbs/gallon

translocate to the roots and kill them. Tree foliage must be protected when using this chemical and it is much more hazardous to handle than glyphosate, having a greater toxicity. Weeds and grasses must be growing to obtain good results. Great care should be taken in mixing, handling and using this material. It has no residual activity in the soil.

The following chemicals have not been thoroughly tested in Georgia, but may have promise as Christmas tree herbicides. Labels must be carefully checked for present restrictions or prohibited use.

1. Amizine[9], a mixture of 1 part amitrol to 3 parts of simazine. Tree foliage should not be contacted. It kills a broad range of plants through foliar action.

2. Amitrole[10] is absorbed through the foliage, kills a broad range of grasses and broadleaved plants, including some woody species. Direct contact with tree seedlings must be avoided. It inhibits growth and affects chlorophyl formation. Amitrole T is probably more effective and a wetting agent improves weed kill.

3. Velpar[11] is water soluble and moisture is necessary to activate it. It may cause injury to conifers. The manufacturer recommends no more than 1 to 3 lbs/A, even on established plantings. It should not be sprayed over the tops of trees and should be applied with extreme care. The effects on conifers vary greatly with soils and environment.

4. Dichlobenil (Casoron 4 G).[12] Courtney (1973) recommended 100 lbs/A in late fall or winter, only on well established plants. Fraser fir is quiet susceptible to this. Use only 1 application annually.

5. Diphenamid (Dymid, Enide)[13] is apparently safe to use, with a 3 to 4 month life in the soil. It will not control several broadleaf weeds such as ragweed, fleabane, cocklebur, and jimsonweed. Four lbs/A a.i. has been recommended. Established weeds and grasses are not killed with this.

6. Dowpon (dalapon).[14] This chemical has been used for Bermudagrass and fescue control. Rates from 10 to 20 lbs/A have been suggested, depending upon the plantation condition.

7. Lasso (Alchor)[15] is a pre-emergence grass herbicide. It has been used to control plants at a rate of 3.1 lbs/A every 60 days.

8. Treflan (Trifluralin)[16] has been used to control crabgrass and other annuals using 2 lbs/A or less. Putnam (1970) has recommended incorporating into the soil 2 to 3 inches after spraying.

9/ Amchem Products, Inc.
10/ Amchem Products, Inc. and Amer. Cyanamid Co.
11/ DuPont product
12/ Thompson-Hayward product
13/ Tuco Products
14/ Dow Chemical and BASF Wyandotte Corp.
15/ Monsanto Chemical Co.
16/ Elanco product

Summary

Trade and brand names in this publication are used only for information. The University of Georgia does not guarantee or warrant the standard of the product, nor does the University or author imply approval of the product to the exclusion of others which may also be suitable. The herbicides mentioned are not meant to be a complete listing that could be used in Christmas trees.

The label on each pesticide container should be read prior to use. Follow instructions to the letter, heeding all cautions and warnings. Each pesticide must be checked for clearance or registration for a particular use before it can be applied.

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STOP #1

MECHANICAL THINNING VA PINE STAND

History of Stand

A 55-year old stand of Virginia Pine (average BA 85) was clear cut and committed to natural regeneration in 1969-70. An adequately stocked stand of seedling saplings was recorded in 1972.

Stand Information

Size: 30 acres
Site Preparation: After clear cut, all residual material was slashed down with chain saws.
Site Index: 70 for VA Pine
Soil Factors: Southerly aspect below 2500'
Bedrock: Fractured phyllite bedrock
Texture: Silty clay loam
Moisture Regime: Droughty

Objective

Virginia Pine will be managed under an even-aged management system with a 60-year rotation. This rotation will produce small sawtimber on the better sites and pulpwood on the poorer sites.

Treatment

May 1977 stand was strip thinned with a K-G blade on a 5 X 12' spacing. Cost per acre was approximately $8 per acre. Before treatment - approximately 2,000 seedlings per acre. After treatment - approximately 700-800 seedlings per acre.

STOP #2

Shortleaf Pine Planting, Comp. 116, Stand 13

Acres: 20

Management Type: Oak-Hickory

Site Index: 70 for Red Oak

This stand was the first one regenerated on the Hiwassee Ranger District through clearcutting. The cut was made in 1965 and planted with shortleaf pine in 1966 after the site was prepared for planting with hand tools. The spacing is 8 X 8'.

The stand was treated by a precommercial thinning and release in 1973.

STOP #3

White pine Regeneration, Comp. 118, Stand 4

Acres: 33

Management Type: Shortleaf Pine

Site Index: 60 Shortleaf Pine

This stand was clearcut in 1970 and the site prepared for natural regeneration with hand tools the following year. The objective of regenerating the stand to shortleaf pine was not successful for several reasons: site preparation must include prescribed burning; shortleaf pine seed crops are not abundant and regular; much advance white pine regeneration existed in which the site preparation released; superior shortleaf pine seedlings were not available.

Part of the area was burned over by wildlife in the Spring of 1973. The white pine has been considerably reduced in this area.

Precommercial thinning and release work was done in 1977.

STOP #4

Recreation Shelterwood, Comp. 122, Stands 11 & 12

Acres: 44 and 85

Age of Residuals: 70 for VA Pine

Management Type: Stand 11 White Pine
Stand 12 Cove Hardwood

Site Index: Stand 11 70 for White Pine
Stand 12 80 for Red Oak

These stands were treated at the same time, 1972, through a shelterwood cut. The area was then site prepared for natural regeneration with hand tools in 1975.

You can tell us what we've got here?

STOP #5

Virginia Pine Regeneration, Comp. 155, Stand 12

Acres: 47

Management Type: VA Pine

Site Index: 70

The stand, predominately VA Pine with some low quality hardwoods, was clearcut in 1974. In August of 1975, a hot prescribed burn for planting site preparation was done on 31 acres. It was an extremely hot burn that was effective. It removed the heavy slash and eliminated the more costly hand site preparation. As steep as some of the slopes are, damage to the watersheds by the fire was minimal. The burned portion of the stand was then planted with 1-0 VA Pine superior stock of 1976. The seedlings have now undergone three growing seasons on the site.

It appears that the prescribed burn was so effective in removing competition that the release and weeding operations often needed for planted stands approximately 5 years old will probably not be needed.

A contrast is provided by examining the untreated southern portion of the stand. Here regeneration is natural. Notice the preponderance of red maple.

STOP #6

White pine Thinning, Comp. 154, Stand 6

Acres: 69

Basal Area: 86 outside roads; 72 overall

Age: 50-60

Management Type: Cove Hardwoods

Site Index: 90 for white pine; 80 for northern red oak

This stand was marked for thinning through commercial sale. The original basal area was 130 and the objective of the cut was to reduce it to 80-90. Trees to be cut were selected: to improve the spacing; select the crop trees; and favor desired hardwoods when practical. The cutting was done in the early summer of 1978.

The management type for the stand is cove hardwoods; the existing forest type is white pine. When the stand is regenerated, attempts will be made to convert it to the management type. The regeneration age for the white pine group is 80.

A problem common to the cove hardwood management type of the Southern Appalachians is demonstrated here. Fire management practices protect the advance white pine regeneration which dominates the stand after heavy partial or regeneration cuts.

Erosion control work was done in October 1978 with annual rye and fescue after fertilizing at a rate of 500 lbs. per acre with 6-24-24.

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